Using 3rd-Party Expression Pedals with ControllerHub 8

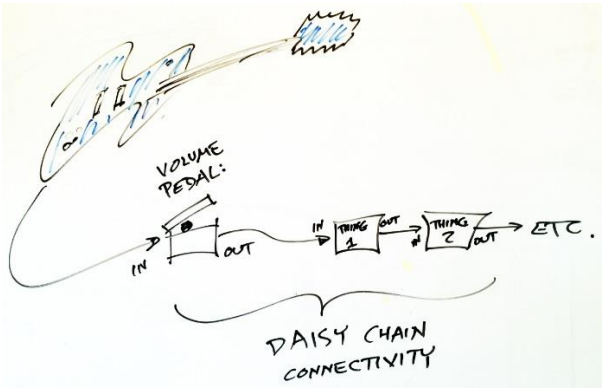
When I first designed the ControllerHub expression pedal interface (and later the PedalPusher expression pedal), naturally I had to make sure these would work with 3rd-party equipment already out in the world. So I ordered a whole bunch of expression pedals. I assumed they would all be the same; I assumed an expression pedal is an expression pedal, duh. Not so! There are a few popular pedal types which are incompatible with the larger, "normal" group of products.

I rather imagine that once upon a time, if a company's product needed an attached pedal, then they would design their own pedal specifically for that product. If you had Brand X's product, naturally you would use Brand X's pedal. But things have evolved, and now people expect that when they buy an expression pedal, it can be used to control equipment from a wide range of manufacturers. Conversely, they would like to buy a piece of equipment and be able to use expression pedals from a variety of manufacturers to control it. In order to achieve these ideals, it would be necessary to have a standard for the circuit inside expression pedals and for the receiving circuitry inside each piece of equipment. That is *almost* the case, but not quite. Thankfully, there are workarounds available.

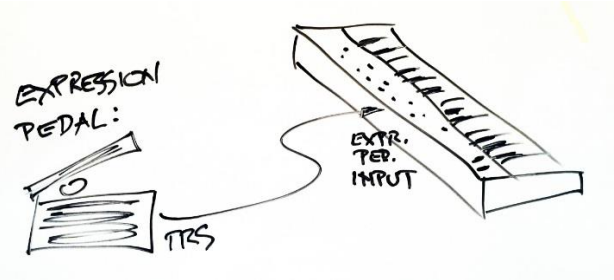
This article explains some of the details of expression pedals, so that the differences between different brands of expression pedals can be understood.

To start with, what's the difference between a volume pedal and an expression pedal? I don't want to get too strict about these definitions, but generally a **Volume Pedal** has two jacks for in and out, and audio passes through it. It has but one function, and that is to change the volume of the audio signal passing through it. In order for it to change the volume of a *different* signal, it needs to be unplugged and reconnected with the new signal running through it. A volume pedal is connected in-line (one of possibly many items connected in an audio daisy-chain) using standard ¼" instrument cables, which are 2-conductor.

I have to apologize – I'm the "artist" responsible for the drawings in this article, which are actually photographs of white board sessions. I hope you can get used to my style! This is my attempt at showing a guitar running first through a volume pedal and then through a daisy chain of stop boxes:



An **Expression Pedal**, on the other hand, has only one jack, and audio does NOT pass through it. An expression pedal is connected using a 3-conductor ¼" TRS cable. It connects to a specifically-labelled expression pedal input jack on the back of a piece of equipment such as a keyboard or guitar stomp box, and its function is to control audio parameters inside the connected equipment. The pedal's purpose is essentially undefined until it is *assigned* to control an internal parameter via the user interface of the connected equipment.



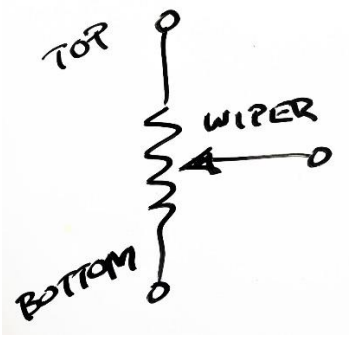
The nice thing is, the parameter assigned to be manipulated by the pedal – the "target" parameter assignment – can be changed without needing to unplug the expression pedal and re-plug it somewhere else. The target parameter can be reassigned via the connected equipment's user interface, and in fact the assignment can usually be saved along with each preset, so that it can thereafter be changed "on the fly" with a simple preset change. So in Preset 3, for example, the pedal might be controlling the master volume parameter. But when the user switches to Preset 5, the pedal might be reassigned to control Reverb level. This allows a small number of physical pedals to be used to control a large array of target parameters, with the caveat that there must be some mechanism to switch assignments on the fly.

So, is it better to have a small number of expression pedals that are re-assigned on a per-preset basis? Or is a more "brute force" approach preferable, where a larger number of pedals are each more-or-less permanently assigned to their target parameters? Ideally, this is a matter of personal style that each musician decides individually. But, until the release of ControllerHub 8, it's been difficult to connect more than one or two expression pedals to one's audio rig. Now, you can do it both ways.

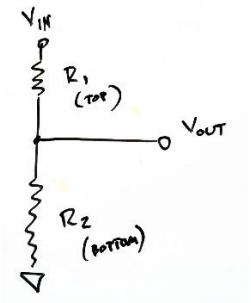
Expression Pedal Circuitry

1. Potentiometer

An expression pedal generally contains but a single electrical component, called a potentiometer – a variable resistor whose resistance is changed by shaft rotation. The design of the pedal somehow couples the potentiometer shaft to the pedal's movement, and now you have a pedal-controlled resistance. Here is a picture of a typical potentiometer and its schematic symbol:



As you turn the shaft, the wiper moves up and down the length of the resistor, effectively splitting the resistor into two pieces of varying sizes, like this:



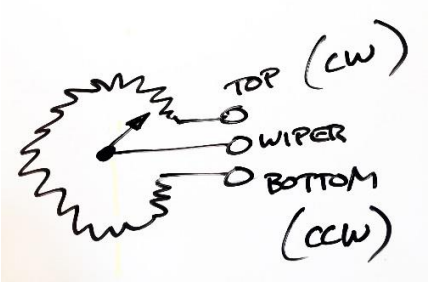
At any given rotation of the wiper, R1 and R2 are fixed. But as the wiper is rotated, R1 gets smaller as R2 gets bigger, or vice versa. The total of R1 and R2 is always the same, and this is the characteristic resistance of the potentiometer. So a 10kohm potentiometer has a characteristic resistance of 10kohm which is split by the wiper into two rotationally-variable resistances that always add up to 10kohm.

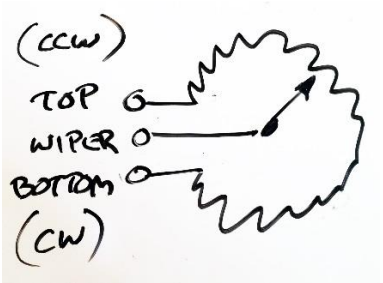
Suppose we connect a constant voltage V_{IN} to the top pin of the potentiometer. The bottom connector we'll connect to ground, or zero volts. As the potentiometer is rotated, the voltage on the wiper V_{OUT} ranges from zero at one rotational limit to V_{IN} at the other limit. For those mathematically inclined:

$V_{OUT} = V_{IN} * (R2 / (R1 + R2))$

This equation just says that the voltage is split by the same fraction as the resistances. So if we have a 10k pot that's rotated to 2/3 of its travel, then R1 = 3.33k and R2 = 6.67k and V_{OUT} = 2/3 of V_{IN}. If we rotate the pot to ½, then V_{OUT} = 1/2 of V_{IN}. If we rotate the pot to 1/10, then V_{OUT} = 1/10 of V_{IN}, etc.

I like to envision a potentiometer like this, where the resistor is wrapped around the inside circumference of the potentiometer body (both orientations are shown):





I think this is pretty close to a potentiometer's actual construction, though I've yet to break one open to see for myself. When you rotate the potentiometer all the way clockwise 'til it hits the CW stop, then the wiper is shorted to the pin labeled CW. When you rotate it all the counterclockwise 'til it hits the other CCW stop, then the wiper is shorted to the pin labeled CCW. In either of these extreme cases, one portion of the split resistor has collapsed to zero and the entire amount of the resistor is given to the other half.

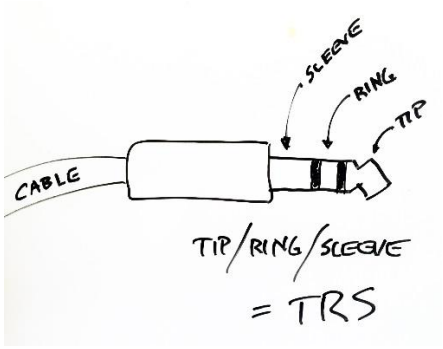
I like to add the "Top" and "Bottom" designators so I can remember which end of the resistor is tied to the higher voltage. I call the pin connected to the higher voltage the Top of the potentiometer, and the one connected to the lower voltage I call the Bottom. You can see from the two drawings that the association between CW, CCW, Top, and Bottom can flip depending on how the potentiometer's been hooked up in the circuit. For linear taper potentiometers

(where the resistance per inch around the circumference is a constant), the situation is completely symmetrical, so the potentiometer can be flipped without consequence – except of course for the swapping of CW and CCW.

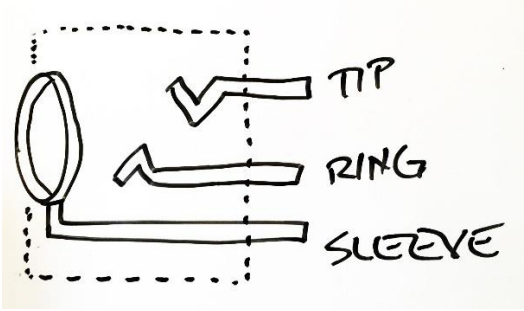
Now comes the tricky part - where the potentiometer is connected to the TRS cable.

2. TRS connector or cable

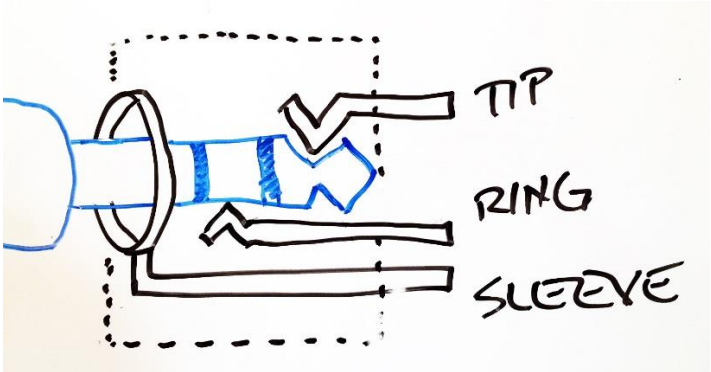
What do you mean, the "tricky part"? There are three connections to be made, for crying out loud – how hard can it be? I'm glad you asked! Here's a male TRS cable connector along with a drawing labelling its three connection points:



Here's a female TRS panel connector along with a drawing showing its internal construction:



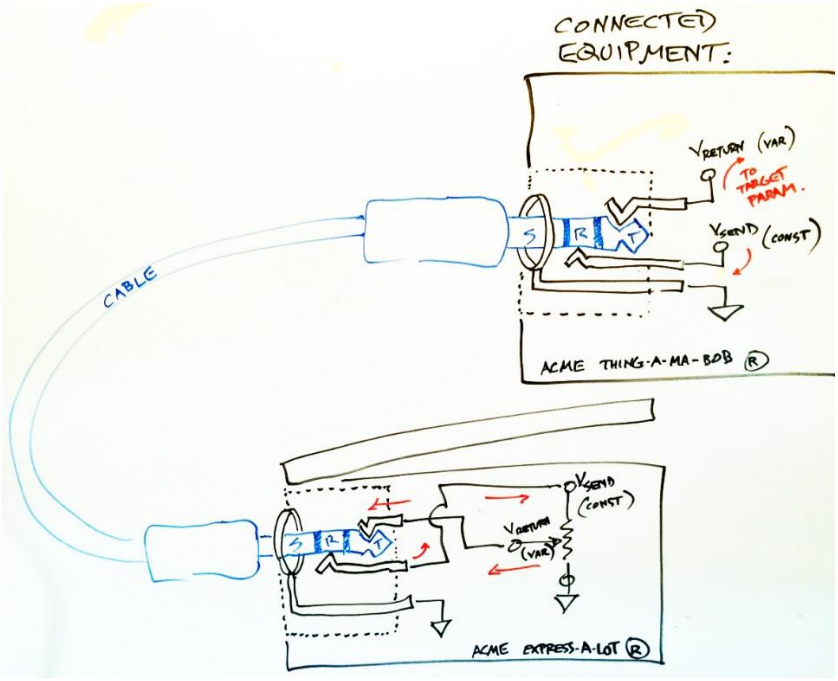
When you plug the cable connector into the panel jack, the connections are made like this:



Some expression pedals have a permanently attached cable, while others have a female panel jack so you can detach the cable:

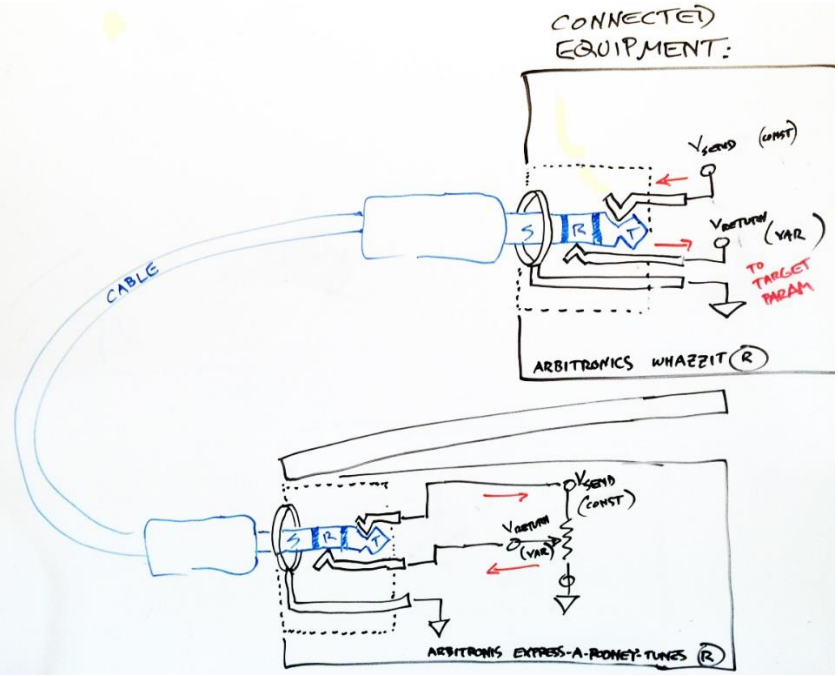
Either way, the internal potentiometer has to be wired to either the TRS attached cable or the TRS panel jack, and again, this is the tricky part! Why is it tricky? Because different manufacturers' wire their pedals up differently. I know what you're thinking: "You've got to be kidding me!". Well, at least that's what I was thinking. I love good rant from time to time, and this inspired one.

Here's how the majority of expression pedals and connected equipment are wired:



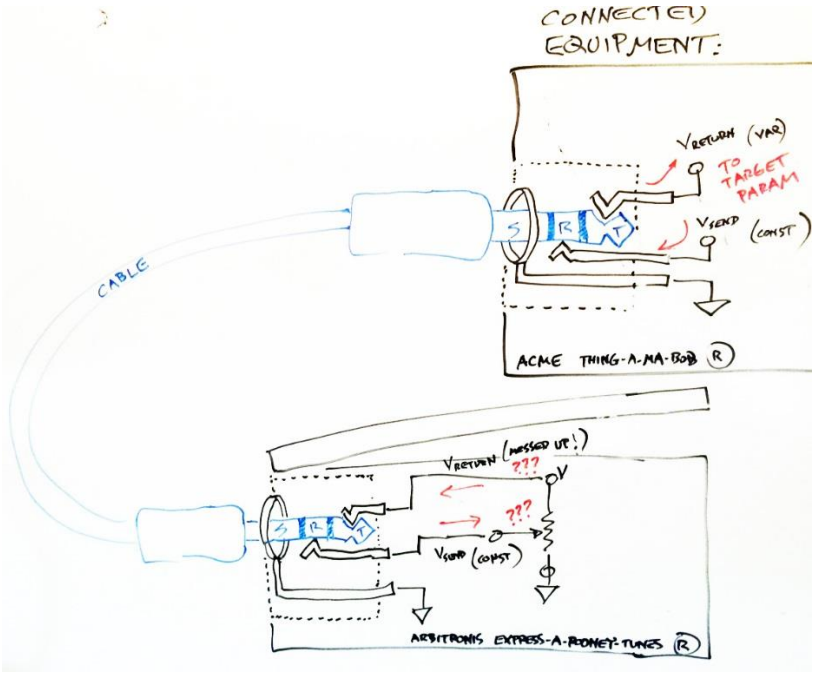
The connected equipment sends a constant, DC voltage to the pedal via the Ring connection of the TRS cable. The expression pedal returns a pedal-varied voltage via the Tip connection of the TRS. This is what the connected equipment expects, so we're in business.

Here's an alternate connection scheme used by a few other popular pedals (such as the Yamaha FC-7):



Notice that the Tip and Ring connections have been reversed at both ends. But again, this is what the connected equipment expects, so we're still in business.

But what happens if we try to connect a "wiper-to-ring" pedal and a piece of "wiper-to-tip" equipment?



The DC send voltage is now erroneously applied to the middle of the potentiometer, instead of the top. I think what happens is that all the current goes through the lower half of the potentiometer to ground, because it's a high impedance connection back to the… ah, let's not speculate any further. Suffice it to say, it doesn't work! And there's a danger of shorting the connected equipment's send voltage straight to ground when the pedal is rotated to its heel position (or toe, if there's a polarity switch). So when checking for compatibility, stay away from the ends of pedal travel.

There are other connection schemes as well (!), but the two just shown seem to be the most common. The result of having expressions pedals in the market with varying connectivity schemes is that users have to do the homework to figure out which pedals are compatible with which equipment. I've yet to come across pedals belonging to any but the two connectivity schemes shown above, so for the rest of this article, they'll be ignored.

Now, let's talk about other differences between pedals and discuss ControllerHub 8's ability to adapt to various connected pedals.

Expression Pedal Variations and ControllerHub 8's Ability to Accommodate Them

Resistance – expression pedals have just one electrical component in them, and this is the potentiometer – a variable resistor whose resistance is changed by shaft rotation. But the potentiometer's maximum resistance (the resistance when the shaft is rotated to the end stop) can be different from pedal to pedal.

The ControllerHub 8 comes out of the box assuming a pedal max resistance of 10k ohm, which is the most common value. But it includes a Calibrate function which allows it to accommodate pedal resistances up to 100k ohm. If you connect a pedal that uses a 10k potentiometer, you'll be good to go right from the start. But it you use a pedal with a substantially higher resistance, say 20k, prior to calibration you'll see that your target parameter hits max long before the pedal reaches the toe-down position, and the top half of pedal travel causes no further change. Or, if the pedal is less than 10k, you simply won't be able move the pedal far enough to reach one end of the target parameter's range.

In either case, simply calibrate the pedal. Press the Calibrate button in the MIDI Designer Editing Template (available from our website), or send the SysEx command (F0 00 02 01 01 00 0*n* 0B 7F F7 - where *n* is the input number) that does this. Now, move the pedal so that it softly touches both ends, and then turn Calibrate back off (F0 00 02 01 01 00 0*n* 0B 00 F7). The pedal and its target parameter are now synchronized such that heel-down results in parameter min, while toe-down results in parameter max, with all the points in between selectable at intermediate pedal positions.

Taper – expression pedals almost always use a linear-taper potentiometer, whereas volume pedals almost always use audio-taper potentiometers[1]. This is because audio actually passes through a volume pedal, whereas an expression pedal is simply a data entry device. But some available pedals are advertised as dual-purpose, able to be used as either a volume pedal or an expression pedal. Often these will use an audio-taper potentiometer for both functions. Users will often comment that this results in the pedal having fast and slow ranges, where rotation of the pedal near the heel-down end causes either more or less change than the same amount of rotation near the toe-down end. In extreme

[1] The difference is in the resistance per linear inch around the inside circumference of the potentiometer. This resistance of a linear-taper potentiometer is constant the whole way around the circumference. The resistance per inch of the audio taper potentiometer, on the other hand, increases toward one end and decreases toward the other. So the wiper crosses through more resistance per degree of rotation at one end than it does on the other. This matches the way the ear perceives audio volume.

cases, all of the parameter adjustment seems to occur at just one end of the pedal's travel, and the rest of the travel causes almost no further change.

ControllerHub 8 has no mechanism to "linearize" an audio-taper potentiometer, but often it's just something that the user can get used to without realizing it. You just come to know where your pedal's fast and slow ranges are, and you no longer have to think about it.

In the extreme cases, however – where it seems that all parameter adjustment is confined to a narrow range at one end of the pedal – the pedal signal may have to be passed through a linearizing process. Fortunately, many of the software programs ControllerHub 8 interacts with – such as MainStage for example – include this feature. In general however, I would suggest that it's probably better to select an expression pedal with a linear-taper potentiometer, especially when controlling hardware devices such as stomp boxes or keyboards, since these won't always be able to compensate for the pedal's audio taper. It's generally much easier to offer the linearizing feature in software programs than in hardware devices.

Weight & Construction Material – Generally expression pedals are either plastic or metal, with the metal pedals weighing considerable more. Weight is a consideration when you use more than one, and with the ability of adding up to eight of them with ControllerHub 8, we decided to develop our own light weight yet extremely rugged expression pedal. Our PedalPusher is made of thick architectural grade aluminum, yet weighs just over one pound.

Rotation Range – the majority of expression pedals have very narrow rotation ranges of 15 degrees or less, sometimes just over ten degrees. There are only a handful of pedals that have an extended rotation range of 30 degrees. The ones we are aware of are the Yamaha FC-7 and Hammond EXP-50. But these pedals have audio-taper, 50kohm potentiometers. There is only one full-30-degree pedal that has a 10k0hm linear taper potentiometer, and that is our own PedalPusher (described in the previous section).

Connectivity – As was discussed at length earlier, expression pedals vary in the way the 3-pin potentiometer is wired up to the 3-pin jack or attached cable. In the design of ControllerHub 8, we had to choose which wiring scheme to be compatible with. A related issue is that we decided it was important to design ControllerHub 8's inputs so that they could switch-hit between on/off pushbuttons connected with standard ¼" instrument cables and expression pedals connected with ¼" TRS cables. As the "switch-hit" wiring scheme is the same as the most common wiring schemes for 3rd party expression pedal, the decision was easy. Specifically, the wiring scheme used has the potentiometer's wiper connected to the Tip connection of the TRS jack or cable. For those using pedals with the less common wiring scheme where the potentiometer's wiper is connected to the ring of the TRS (including the Yamaha FC-7 and the Hammond EXP-50), we offer our 4" Expression Pedal Adapter Cable as an add-on.

The adapter cable has 3 wires: white, black, and shield. The shield is connected to the Sleeve on both ends. But on one end the white wire is connected to the Tip, while the black wire is connected to the Tip at the other end. If the pedal has an attached cable, this adapter simply gets added to the end of it. If the pedal has a detachable cable, on the other hand, then the adapter can be attached at either end. Click here to purchase one from our website.

We are gradually creating a database of 3rd-party expression pedals. This will include the wiring scheme, the potentiometer R_{MAX}, and the resistance vs. rotation curve.

Finally, click here for an article on expression pedals in general, written by a very helpful author at Mission Engineering (who also make excellent expression pedals, by the way!)