Optical Pickup Blog

16th July

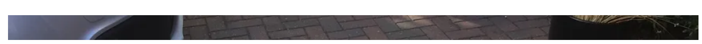
After the research assignments have been handed in, it is now time to start thinking how my own optical pickup will be designed. As I am planning this to work on my EUB, I need to make it better sounding than the original piezo pickups, and hopefully more practical. After looking at the 'Make' project again, (https://makezine.com/projects/infrared-string-bass/), I can see how the initial idea will come into shape, but also wonder why they are using rubber strings. Is it because the amount of movement in the string needs to be so large in order for the optical electronics to see a signal? The structural side of the test instrument also looks a little agricultural, and I am sure I can come up with something that will be a little more musical like as a test instrument. I have some components that can be used, ie a bass bridge and some tuning pegs, and I can source some wood to make the body. Components will also need to be researched, although there are some links on the 'Make' web page to be used as a guide. After trying some of these links, it took me through to an American electronics store, but not to the actual items needed. A wider search through some English electronics stores gave a vast range of options, and after some consultation with a friend who works with electric musical instruments, his advice was to use Light Dependant Resistors (LDRs) as a receiver, and LEDs as a transmitter. While he is very knowledgeable in the repair of electronics, he has never used LDRs, or Phototransistors in this way before. I wanted to use the infra red spectrum, as there would be less interference from regular light, hopefully giving a cleaner signal. Reading through the spec of several items, it became clear that some were used to switch on or off, depending on the light received, and I suspect these would be used in alarm systems, machinery, etc. I needed a receiver (LDR or Phototransistor) that would give a varied signal, depending on the variation in the string movement. Some more research may be needed in order to find the right type of component.

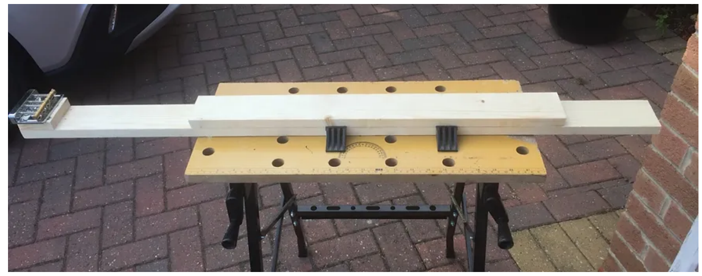
25th July

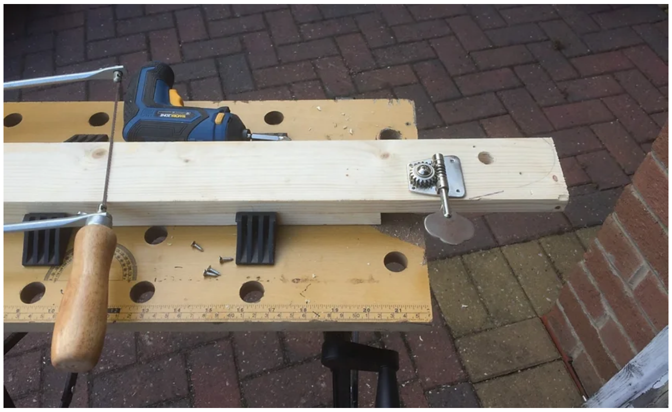
Components have now been sourced and ordered. I have opted for infra red phototransistors and infra red LEDs, 3mm size. I have checked their compatibility for 'seeing' each other, as they both transmit/receive within the same light frequency spectrum. (The LEDs operate at a frequency of 950nm, while the phototransistors operate between 730-1200nm). Other components will be needed for the circuitry and op-amp, but these will be decided upon once the initial testing of the optical components has been done, or more importantly, successful.
Upon reflecting on the placement of the LED and phototransistors that have been used by other designs, I will start by having them either side of the string. This should make the design of the tunnels easier to allow for height adjustment, not having the components above and below the string. In some of the previous research, some designs had either more then one phototransistor set up, using a triangulated design, or had 2 transmitter/receiver units aimed at the string, 90 degrees apart, picking up light as a reflection, rather than as the actual string movement. The purpose of some of these designs is to see more of the rotational vibration of the string, rather than just a 2 dimensional view. Having the Led and phototransistor either side of the string will only see the up and down motion of the string, not any side to side. While it can be assumed that the string vibrates freely, giving the same amount of motion in either plane, the initial attack direction, ie the direction the string is plucked in, may give a stronger or weaker signal in one plane, which would even out as the string vibrates. I had the idea of using 2 pickups per string, one to see the side to side motion, and one to see the up and down motion. This should give the full spectrum of sound produced by the string from the very first attack, until the string vibration dies away. Another thing to be considered in how a string vibrates is the node points that are produced. These are points of little or no vibration that occur as the waveforms cross the string. Having 2 pickups placed slightly apart will also virtually eliminate the problems caused by node points, as there should be no node point seen by both pickups at the same time. Having the design to encompass the 2 optical pickups in one tunnel may prove to be a little problematic in terms of allowing for adjustment, but this is something that I would like to pursue as a future design.

1st August

My main problem is now how to mount the 'tunnels' on the instrument, allowing for some adjustment in height to match the optics against the height of the string (the action). I imagine a scenario where there is a wooden block attached to the instrument, into which I can screw the 'tunnels', with either a spring fitted in between, or some material that will compress and give sponge-like properties. This should apply some upwards pressure against the screw, which is applying downwards pressure, keeping the 'tunnels' in place, depending on how far they are screwed down.
Work has now started on constructing a test instrument for a prototype. I will use a conventional bridge and tuning pegs from an electric bass, along with some wood that has been sourced from the local Wickes store. A basic design is in my mind, that has the bridge and fingerboard sections mounted on double thickness wood, leaving a space between the bridge and neck to allow working in and making adjustments.





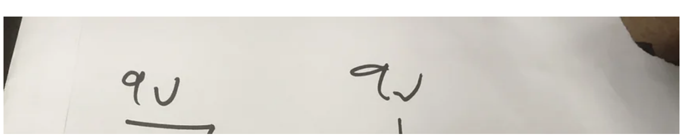


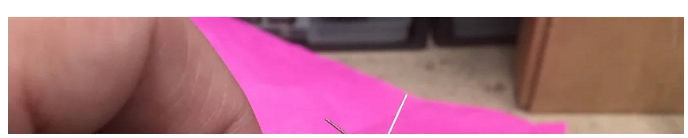
6th August

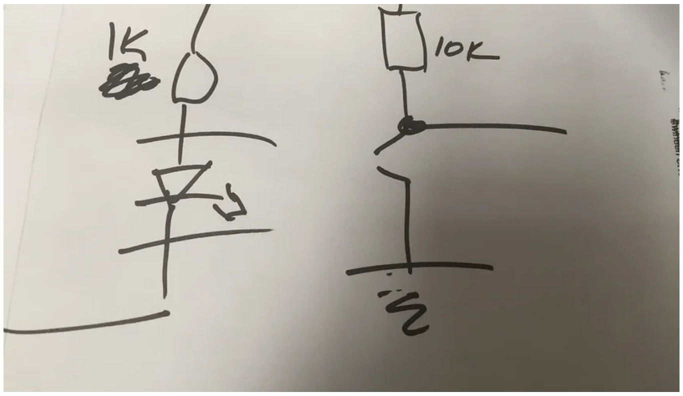
The test instrument has now been finalised, with some smooth finely compressed cardboard used as a fingerboard. While the strings are held in place on the bridge with bridge saddles, something was needed to hold them in place at the other end of the body, near the tuning pegs. A ‘nut’ is commonly used, which is usually made from plastic, brass or bone, and has slots cut into it for the strings to be held in place. Due to the basic nature of the instrument, the neck and fingerboard are too wide for a conventional nut to be put in place. It was decided to use a cap head slotted screw, with the slot filed a little wider to allow the string to sit in the slot a little deeper. These were screwed into the correct position to allow a straight line of the string from bridge to tuning peg. Due to the type and size of wood being used, it is only possible to put 2 strings on, as there is not enough room to put 4 tuning pegs. This will be fine for testing, as only 1 string needs to work, then everything can be copied for the other strings.

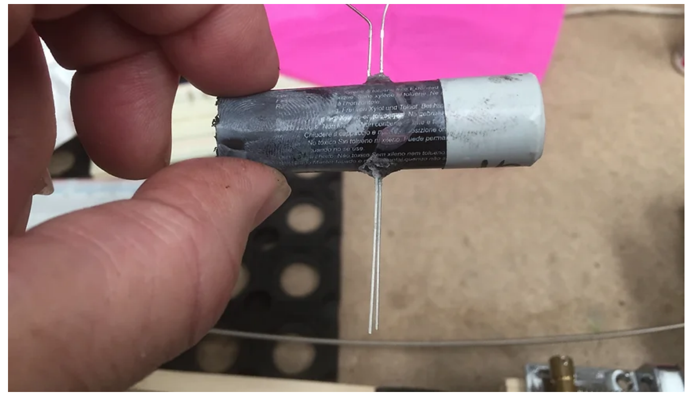
14th August

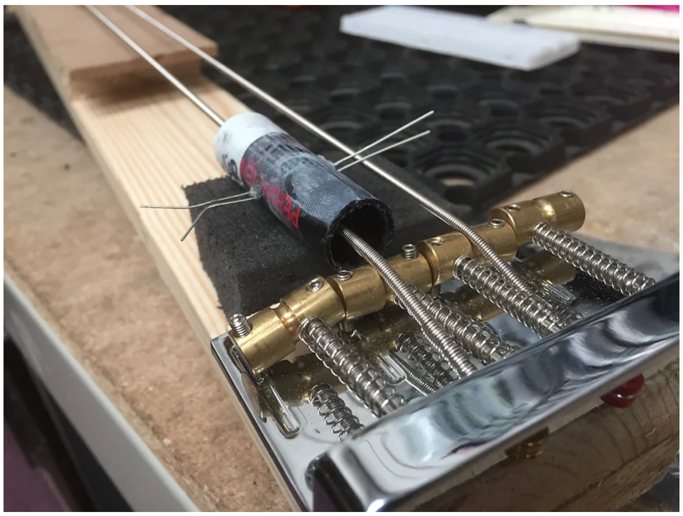
The first test of the LED and phototransistor, with Rob Arnall of Pro Audio Services. Rob is a friend who is an electrical repair guy, specialising in musical instruments and amplifiers. He is happy to give some advice on electrical items, but does not have the time to put into helping with the actual build or design.
a basic tunnel was put together from a body of a permanent marker, then holes were drilled in the side to put the LED one side, and the phototransistor on the other. They were glued into place, then Rob worked out what size resistor would be needed to bring the voltage down from a 9volt battery to a voltage that the LEDs could work with. Initially, Rob decided on a 1k resistor for the LED and a 10k resistor for the phototransistor. Some foam was cut into the correct size pieces, in order to place the ‘tunnel’ with the LED attached at the correct height of the string on the test instrument. At first, it was difficult to get a signal, so we tried using a regular LED, not an infra red one, as it could not be seen whether the infra red LED was working or not. The red LED worked fine, and it produced some signal, but nothing that would be classed as successful, as it was too small. After much head scratching, Rob thought that maybe the phototransistor was not getting enough voltage to produce a big enough signal, or to work correctly. As the LED was using a 1k resistor, this value was also tried on the phototranistor, which then gave a much stronger signal. Now that something was showing on the oscilloscope, and it was clear that it was a strong signal, Rob got some extra bits of wire, and connected them to an xlr cable, which was plugged into a mixing desk used for playing music and testing equipment. Almost immediately, there was some noise from the instrument when it was plucked. It worked, and was actually quite a nice sound. There was some background noise, but this was understandable, as there were bare cables and bare joints everywhere. The main purpose was to test whether the idea and the components would work, and to this end, it was successful. We were quite surprised that the bass sounded as good as it did, with just the basic components, held in place with fingers and crocodile clips.
Next step is to make the ‘tunnels’ more secure and have the components attached properly in order to see how it works and can be adjusted.

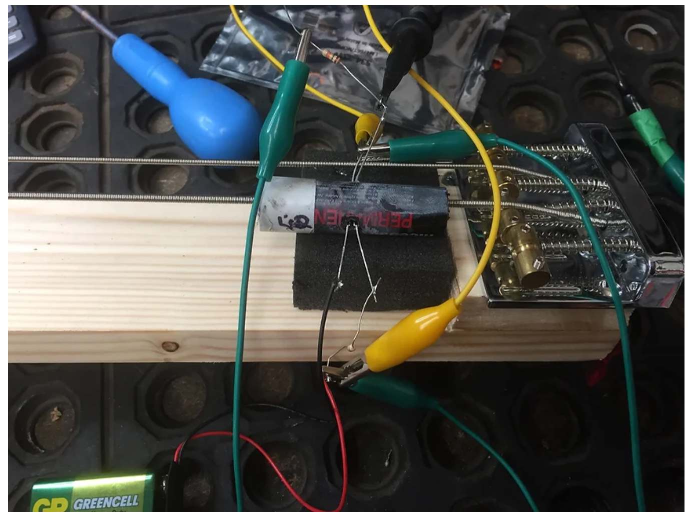










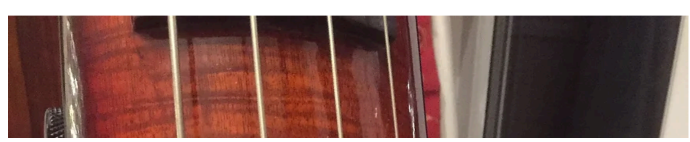


Getting First Strong Signal

Hearing Sound For The First Time

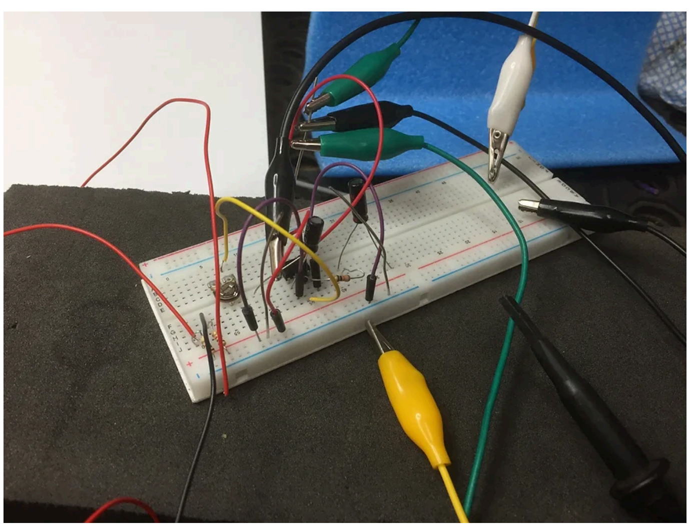
17th August.

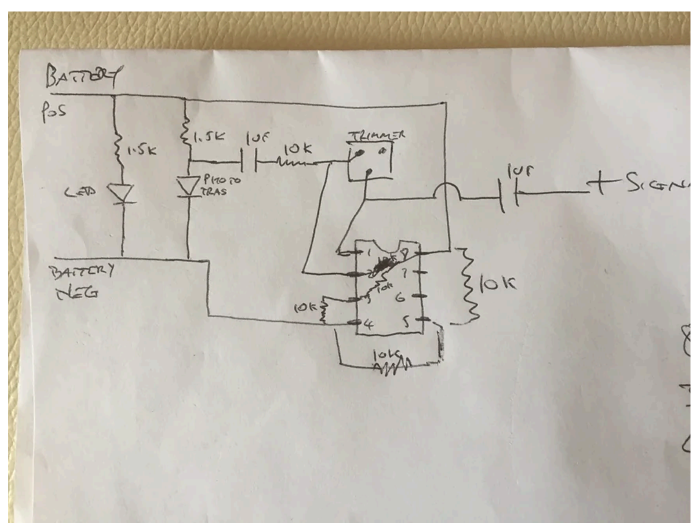
This week was spent sourcing different parts to make the ‘tunnels’ and to explore how they will be mounted. I initially bought some 16mm square conduit, as I felt that it would be easier to mount a square tunnel, and make it easier for adjustments. It also has a removeable top section, so this will allow for access to the LEDs for fitment and adjustment. Upon cutting to size, I realised that the walls of the conduit were too thin to hold an LED fitment, so another option was explored. On searching through my garage, I came across some aluminium rack for holding shelving. As luck would have it, this was also 16mm, already painted black (to help keep out any light), and the removeable tops from the conduit fitted perfectly as a ‘lid’. The ‘lids’ were painted black to match the tunnels. As the tunnels already had some holes cut into them (where the shelf bracket would have been installed), these were utilised to allow a screw fitment into a block of wood on the test instrument, with some foam in between to allow for some height adjustment. A similar design will be used on the actual bass, but as the height from body to string is quite minimal, only a thin section of wood will be used, held onto the body with double sided tape, so as not to damage the instrument. Some LED holders were ordered and holes were drilled into the sides of the tunnels to allow fitment. As there is not much height on the actual bass, the adjustment screws needed to be small, but also have a good enough thread to tighten into the wood strips. After a visit to Screwfix, some special screws were purchased, but even then, these were a little too long, so approx. 2mm had to be cut off each one, otherwise they would have gone through the wood strips, and into the body of the instrument. 5 of these tunnels were made, 4 to go on the electric bass, and 1 for the test instrument. Upon fitment to the bass, it was noticed that there was not enough clearance between the strings for the LED holders, so they were cut down to size accordingly.



24th August

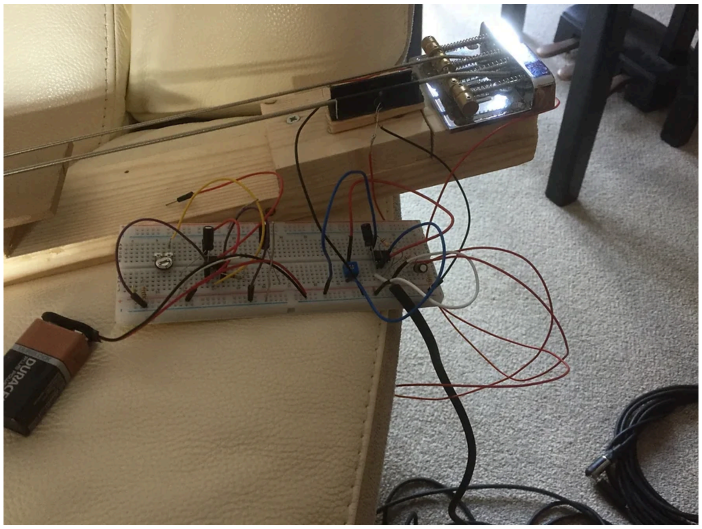
After it was found that the basic concept and components will work, a circuit will need to be designed to allow for amplification of the signal through a basic op-amp, as well as individual level setting of each pickup. This will be needed, as the strings on an instrument are different diameters, so may give a stronger or weaker signal accordingly. Having a level control on each will allow for matching the output from each string. I had previously purchased a ‘breadboard’ for test building a circuit, and on another visit to Rob’s workshop, some components were tried to see how the circuit will be built. A simple circuit was designed, but this used an op-amp that relied on mains power and an equal + and – voltage. The circuit needed to be portable for use on an instrument, and rely on a 9volt battery for power. After searching through electronics catalogues, Rob advised on using 2 x LM358 op-amps, as these will work fine with a 9v battery using 9v + and 0v -. They also have 2 op-amps in each chip, so will save on components used. The op-amps and other components were ordered, along with some veroboard to solder the components onto.

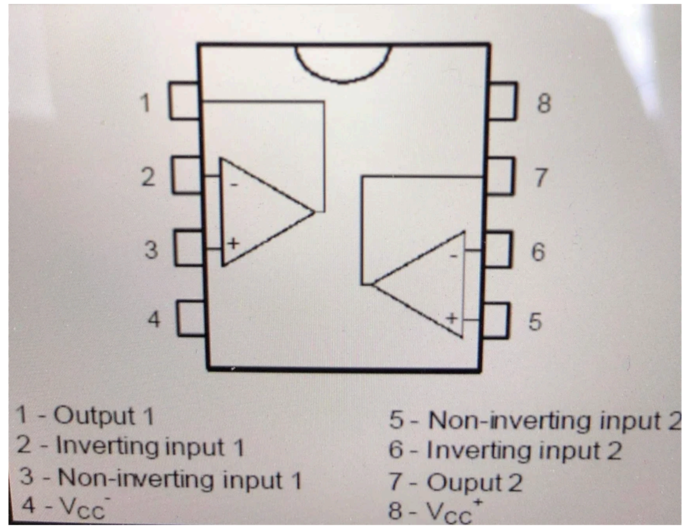




3rd September

All components have been sourced, and the basic circuit has been built using some of the breadboard as a test to see if the components are all compatible. The circuit was successful, but did have some slight hiss noise at a low level. This did not affect the sound very much, as I am used to some slight noise on a normal magnetic pickup on a bass. Initially, the sound was quite loud, but the trimmer was not working at all. Under investigation, it was found that I had not connected + and – to the op-amp, so this was not operating correctly in the circuit. Once power was connected to the op-amp, the sound was quite loud and distorted, no matter what level the trimmer was set at. After a phone call to Rob, he established that a 10k resistor was needed across some of the pins of the op-amp from positive to negative, in order for it to work correctly. Once these were in place, the circuit worked fine, and the trimmer was used to set the level of the signal.





10th September

The circuit has been built onto the veroboard, but has caused several problems. After a lengthy testing and re-soldering session, some components had not been soldered into the correct position, and there were a couple of solders that were not quite correct. After 3 circuits have been built out of the 4 needed (one for each string of the bass), the first circuit does not seem to work at all, while the other 2 do work, but with some crackly connections. The crackly connection was later found to be the main output lead that will be used to connect to an amplifier. It can be noted that the pickup is working without a cover on the tunnels. Although light is getting in to the tunnel, the LED and phototransistor work in the infra red spectrum, so normal daylight does not seem to affect the pickup. Under working conditions on stage, I Although a full test has not yet been done, from what I am used to hearing through the amplifier, the optical circuit seems to be producing a very clear, rich sound. The bass string is vibrating freely, and there is some finger noise, very similar to using a fresh set of strings on an instrument. This sound may not be to everybody's taste, but I think it is better to have a full range sound with plenty of clarity that can then be adjusted through various EQ settings, rather than have a dull, or weaker sound to start with. it would be best to have the covers on, as there may be some elements of infra red light transmitted in stage lights, depending on the colours used.

Optical Pickup on Test Instrument

17th September

Getting very close to the deadline date, and still need to finish getting the circuit board with all the circuits complete and working. Some components have been reordered to make the veroboard circuits again, as there was some messy soldering on the first circuit. Hopefully, experience will now make a completed, fully functioning circuit.

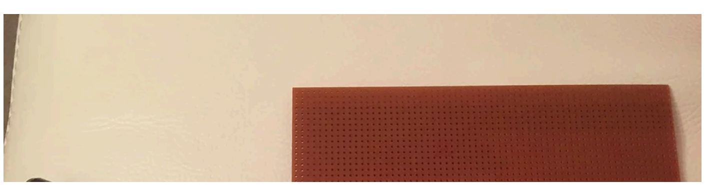
20th September

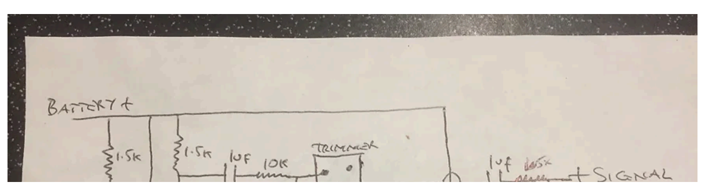
New circuit board started to be built. A few tweaks to the design, allowing for all outputs on the same part of the circuit board to keep the design neater. As the negative is common to all components, only one output will be used, keeping leads to a minimum. Testing of the first output (videod) showed that the circuit works well, with very little background noise, and some different notes were played to show how the test instrument sounded, along with producing some harmonics. The harmonics were produced cleanly and clearly, just as efficiently as a magnetic or piezo pickup.
Hours have been spent with a soldering iron in hand, late into the night in order to complete the circuit.

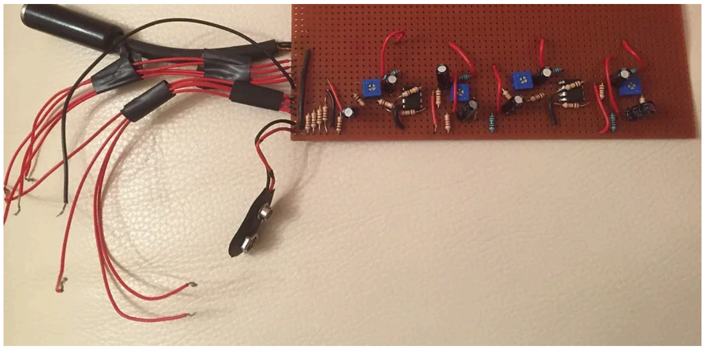
Testing new circuit

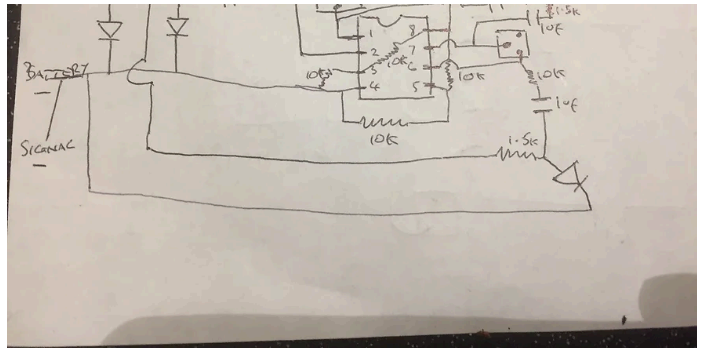
21st September

The circuit has been made, but under testing, it is found that the individual outputs are not all working correctly. After a brief phone call to Rob, it was established that resistors are needed on each output, otherwise the individual outputs are short circuited together. After putting a resistor on each individual output, the circuit started showing other problems. Sometimes, there was no output at all, but occasionally, a couple of the outputs worked. Time was spent re-examining the circuit, and a few cracks in the copper rails were detected, one on the positive input from the battery, which would explain no output at all. Once all of these lose connections had been resoldered, the circuit was tested again, only to reveal that 2 outputs worked, while 2 didn't!







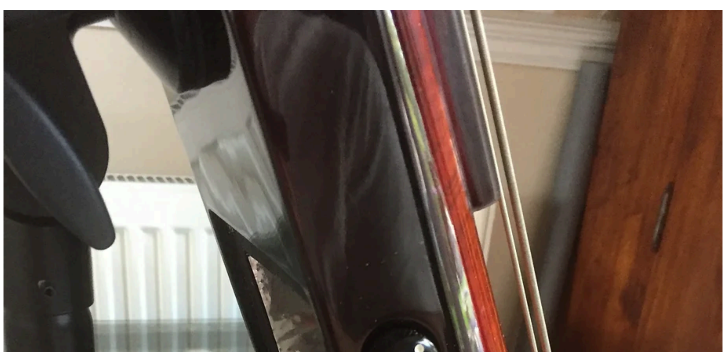


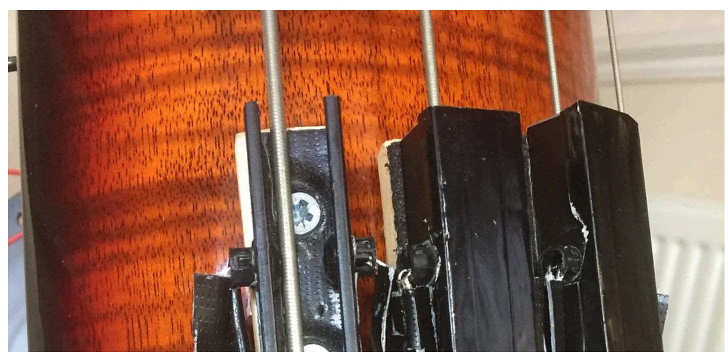
24th September

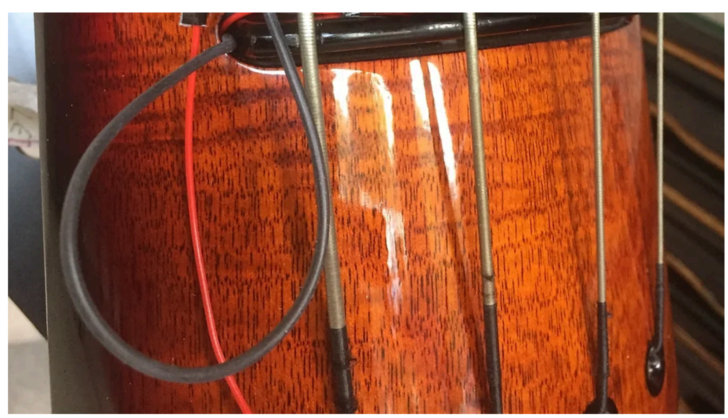
After closely examining the circuit, it was found that there were a couple of connections not fully made, a couple where the solder may have gone onto another track, along with another couple of tiny cracks in the copper track. I'm beginning to think this is a cheap veroboard, as there have now been several breaks in the copper track, or it has lifted away from the board. Once close examination has been completed, and all joints fully made, the circuit was tested and everything finally worked as it should.

25th September

Time for fitting and wiring of the pickups onto the bass. Three of the pickups had already been fitted, using a piece of wood attached to the bass with double sided sticky pad, then the pickup was screwed to the wood with a piece of foam in-between to allow for height adjustment. The 4th pickup did not have enough space for the piece of wood, as the string was closer to the body of the instrument (G string being the thinnest is normally lowest in height). Three double-sided sticky pads were used to set the correct height, then the soldering of all the LEDs and phototransistors was completed.







The wiring of all the LEDs and phototransistors was going to be tricky, as I did not want everything showing. There was some space around the bridge of the instrument, and after testing with a wire, it was shown that it could lead to the control panel area at the back of the instrument, where the original wiring is situated. After much fiddling, the wiring from 2 pickups was routed from one side, and the other 2 pickups was routed the other. As there was not enough room for all the negative wires (8 would have been needed ach side), I decided to link them together as a common negative, only feeding one negative wire from each side. This made 5 wires per side, which just fitted through the gaps. After labelling each wire, connector blocks were used to terminate the cables in the control panel area, keeping the bass looking neat.

26th September

Sourcing a box to house the circuit was a little tricky, but eventually, I found a triple electrical wall socket in B & Q that was big enough, without being too bulky. Only problem was, they didn't stock a blank front for this size box, so a double and a single were purchased, which need to be cut down in order to be the correct size. Packaging foam was used to fill out the inside, and hold the circuit board in place, while holes were channelled to allow the wires in from the back of the instrument and the output socket to be accessed.

27th September

Final assembly and first play of the instrument.
Before final assembly, the circuit was tested to make sure there was continuity to all outputs. The readings were consistent across the outputs, so I was hopeful that it would all work correctly. On first plugging the instrument in, there seemed to be a little noise in the circuit, as the instrument was moved. This soon settled down, and first playing was tested. Bearing in mind there were no volume or tone controls (only a trimmer on each individual pickup), the sound was very good in comparison to the original piezo pickup, although volume levels were not consistent across the strings. The trimmers were adjusted for each string, but the levels could not be matched just by this adjustment alone, indicating that the pickup height may need some adjustment for each string, or there could be a problem with the circuitry, as this inconsistency has been encountered before when testing the circuit. The amplified sound was consistent with the acoustic sound of the instrument, seemingly adding no colour or tonal variation. This was to be expected, as the pickups were giving a true representation of the string, and the sound it produces. The actual sound of the string is dictated by the size and construction of the instrument, ie the woods used, the size and shape of the body, bridge materials, etc. The natural sound (acoustically) of the instrument is neither a full double bass sound, nor a fretless bass sound, but somewhere between the two. The scale length of the instrument (bridge to nut), is 42 inches, which matches the commonly used double bass size (known as ¾ size). A regular fretless bass is 34 inch scale by comparison. Having no body to speak of, the instrument is essentially just a neck with a headstock for the tuning pegs, and a small 'body' to house the bridge and electrical components. It would not be expected to give a true upright double bass sound, having no body cavity for the strings to resonate with, which produces a rich, deep, 'full bodied' sound. The original piezo pickups also give a representation of the string sound, but they sound quite thin, bright and slightly 'harsh' in nature. To combat this, I always turn the tone control completely down, which reduces the higher frequencies, and makes the sound more even across the frequency spectrum. The optical pickups by comparison seem to have this tonal quality already, indicating that their frequency response is more natural and even throughout the frequency range. There were no obvious peaks or dips as the instrument was played from the lowest notes, up through to the highest, although the unevenness of the string volumes made this difficult to assess with accuracy. When using a bow on the instrument, the sound was similar, but lower in volume. This may be because the bow does not produce as much vibration in the string as a full pluck with the fingers, but using a bow could give more subtlety, as the amount of vibration can be finely controlled. To combat the change in volume between the two styles of playing, the original electronic circuitry for the piezo pickup has a switch, which gives a tonal variation and volume boost when used for bowing.
At this point, the instrument has not been tested through any frequency analysers, or other sound measuring equipment, and these are only first impressions, gathered from experience of using the instrument previously through a familiar amplifier in familiar settings. The overall sound is of a similar quality to the piezo pickup, albeit more natural and even across the frequencies, but one of the main advantages is that the instrument itself is no longer amplified. The piezo pickups by their nature rely on amplifying the vibration that occurs with the instrument as picked up through the bridge. This means that any vibration is amplified, including any knocks, scrapes or otherwise body noise associated with the handling of the instrument. Effectively, the instrument itself becomes a microphone. This, to me, is one of the main problems associated with using piezo pickups, along with their then, bright, brittle sound. To this end, one of the problems of piezo amplification has been eliminated, as the optical pickups are only amplifying the vibration of the string and not any noise associated with the body of the instrument.
As an initial test, I am happy that the optical pickups work, and produce a good quality sound, giving a natural representation of the string, and has none of the background noise associated with vibration of the instrument. Further and more detailed assessment will continue as the instrument is used more, and connected to sound measuring equipment.

First test of optical pickups on instrument

First test of bowing

5th October

Some minor surgery to the circuits in order to try and get the output levels the same across all the strings. Before the circuit was put into the housing box, the levels did seem consistent, but were not right once the instrument was played. There were a couple of loose connections, which would explain the noise upon first plugging the instrument in. The earth wire on the output cable was brushing against the positive, and as there were some frayed edges, this was obviously causing problems with the circuitry. The earth wire from the pickups to the circuit was also loose, as the connection block screw had managed to cut through the wire. This wire needed replacing, as it was now getting short, so more soldering was needed to replace this.
Once the circuit had better connections, it was plugged in, and there was no background noise. The E string was raised slightly by adjusting the

bridge height, then the levels were reset using the trim pots for each circuit, testing against the level of the other strings. Upon completion of these tasks, the instrument was ready for another test. Now the levels were even across the strings, it could be played with more feel. The responsiveness of the pickups was very good, as there was no latency at all, and they picked up even the slightest vibration of the strings. The instrument has good sustain, and the pickups responded to this very well, holding onto the note until it eventually died away. Subtleties of playing the instrument, including vibrato were also projected very well, and the pickups gave a very good representation of what the instrument sounded like acoustically. Thoughts about the sound from the first test were agreed with, as it still sounded similar to the piezo pickups, once the tone control had rolled some high frequencies from the piezo sound. The natural piezo sound is overly bright and thin in my opinion, and needs the tone control turning down to make the sound warmer and less harsh. The natural sound of the optical pickups already has the natural warmth and smoothness to it, possessing none of the harsh, brittle higher frequencies associated with the piezo. The instrument can be played with or without the covers on the tunnels, as they are infrared, and are not susceptible to regular light. In a home environment, this is not a problem, but under stage lighting, there may be some light that could be close to the infrared spectrum, which could affect the pickups, so covers would be used on stage.

Them Heavy People - Babooshka - Live