Coati Console Project -

Stage 1 : Initial Evaluations of components and modules

Preliminary Prototyping

At the time of writing, two preliminary prototypes have been assembled and tested individually and with each other. Initially the component modules were fixed to a fibreglass board about 20cm by 30cm square, using a hot glue gun but later, as modules were being swapped in and out for testing, the majority of the components were left loose to make it easier to change the configuration. Testing of the loosely assembled consoles proved the design concept to be viable, with signal routing all working as intended, and suitable audio levels being achievable throughout the system.

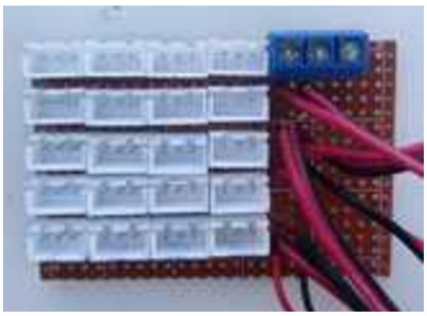
Internal wiring and connections

Connections between the modules was super easy thanks to the standard JST pin header pre fitted to many of the modules purchased for testing. It quickly became clear that it would save a great deal of time and effort if as much as possible of the internal wiring could be done using JST terminals and pre-assembled connector cables. These connections also reduce the amount of soldering and potential soldering errors, making assembling and repairing the console a much more accessible prospect as per the design spec.

In many cases it was fairly trivial to fit JST headers to modules that did not come with them, but for some components this was much harder due to inconsistent pcb holes or pin. Given the huge advantages the universal use of JST connectors offers, we would strongly recommend choosing modules and components on this basis, even if it means some additional upfront coss..

Signal routing

Our early attempts at wiring for the multiple signal paths required between the various elements of the consoles without recourse to JST headers throughout proved frustrating. There are basically four audio signal channels (three relay language buses plus the floor signal) to be distributed to five different internal elements (the two ‘receiving’ sections, the microphone section, the tx output conectors, and the console daisy chain connectors). Given mono pairs, that’s at least eighty connections to be made in the signal paths alone. Since most of our modules are stereo, and we’ve currently chosen to maintain use of twin channels where possible internally, that adds an additional 50% more connections, bringing the total up to over 120!



Fortunately, most of the modules already featured JST headers, and when we purchased a load more, we were able to design a simple and effective signal distribution hub based on a single vero strip PCB board. Obviously this doesn’t completely eliminate the need for soldering, but it does massively reduce it, and means that the vast majority of the remaining soldering is in assembling the signal hub board itself which is pretty easy to do and to test it has been done correctly. We may well consider offering pre-assembled signal hubs to further simplify other peoples construction of consoles in the future.

Power rails and supply voltages

There are at least three modules requiring connections to power, more likely four, and at least three more if not using passive switching. It seems sensible to take a common supply rail approach incorporated into the signal hub board. This could consist of multiple voltages to supply different voltage needs for different modules, however another lesson learned early on was that although it is possible to supply different modules with different voltages, such as 12v and 5v, it is probably unwise to opt for a design requiring multiple internal voltages when it is so easy to standardise on one during the choice of modules. We blew up several headphone preamps during module evaluation due to losing track of the fact they needed 5v max. We opted to stick to 12v nominal supply voltage throughout. It is no doubt possible to put together a successful design based entirely on 5v modules, which may offer some advantages in terms of potential battery powered operation, but given time constraints and the fact that most of our evaluation modules ran on 12v, we decided not to pursue the 5v option further at this time.

Amplifier Modules

While evaluating the various pre-amplifier modules we purchased for the purpose, we noticed that some of the amplifiers we had bought to use as headphone pre-amps would also work as mic pre-amps. Given the design criteria calls for a modular construction that aids easy troubleshooting and repair, the idea that we could use identical amplifier modules throughout is an attractive proposition. That said, the module in question did cost a little more than some of the other options.

It is worth noting that that particular pre-amp module was also the only one we purchased for evaluation that features a built in volume control. A built in control may limit console control layout options, but it also reduces the amount of internal wiring and additional components therefore making assembly quicker and less complicated. Until we attempt to build assemble prototype in cases, whether the advantage of having less restrictions on control placement will be greater than the disadvantage of having to have more wires and connections.

Another thing worth mentioning about the amplifier module described above is that it uses the 5532 op-amp chips used in other Coati equipment. As standard it has x5 gain but that can be increased by changing a couple of resisters. It uses two 5532 chips, one for each channel, and I experimented using just on of these amps with two different mono signals and two independent volume controls and headphones.

Most of the smaller cheaper pre-amp modules were bare boards without JST connectors and no potentiometer for volume control. In order to even be able to evaluate in use, we had to piss about adding connectors or cables, supplying power, and adding volume control. This added lots of extra variables so the results were not really conclusive. In fact, none of pre-amps we did manage to evaluate at this stage seemed to provide sufficient amplification by themselves to get the desired signal level. This was simply resolved by adding a second amplifier in series, a 5532 based amp with convenient JST connectors. Given a different choice of pre-amps, or perhaps resolving some issues we missed when doing the initial tests, using two amps may well prove to be unnecessary, but for the time being we moved ahead by using two stage amplification for the microphone. Obviously this does increase component cost and complexity so if an adequate single amp solution could be found, it would be preferable.

VU Meter

I could not figure out a way to have a ‘clipping’ warning LED as featured on the ALIS consoles so opted for a VU meter instead. It cost under one euro but the way it is constructed is very very inconvenient when it comes to fitting it in a case so the LEDs can be seen. That said, the device proved to offer additional unintended features. When the power to the console is switched on, the VU meter lights up briefly, a good visual indicator that power is present without having to have a specific power indicator. Furthermore, the presence of the VU meter provided an extremely useful troubleshooting tool when diagnosing audio issues. By incorporating a probe lead, it was possible to trace an audio signal throughout the device in order to find problems in the signal path such a loose connectors or a failed amp.

Channel selection switching

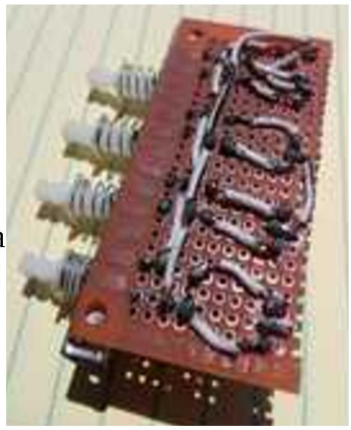
Various methods of signal switching have been considered and explored. In our preliminary prototypes we tried two different active relay based switching modules and three different passive mechanical switches. All seemed to work adequately but none can be considered ideal. The mechanical switching was no doubt the cheapest option, but not by much.

The cheapest of the mechanical switches required the most soldering, nothing too challenging but it adds to things to go wrong. The more expensive mechanical option came as a module with JST headers and connecting cables. This made direct comparisons based on price difficult to assess.

Also hard to assess with such limited short term evaluation is how long the mechanical switching option might continue to work flawlessly. It is possible that long term use would introduce crackles and other noise to the audio signals while switching. For these reasons we believe mechanical switching is most suited to the input selection elements of the console where some noise may be more tolerable, rather than the output switching side which could effect many more users downstream.

With one exception, the switching methods we have available to us for evaluation all suffer from another potential drawback, they all switch sequentially through the options. For example, if your switch is currently on position 1 and you need it on position 4, you must pass through positions 2 and 3 to get there. In the context of the console, when switching input channels from 1 to 4 you would briefly hear the signal coming in on channels 2 and 3. This is not a problem, however, on the output selection side of things, as you switched from 1 to 4, you would briefly be outputting a signal on buses 2 and 3, potentially creating interference and disruption. For this reason, ideally the output selection system would not be sequential but instead allow you to jump from 1 to 4 directly etc.

We had one non-sequential switch to evaluate, mechanical interlocking push button switches. This was cheap and seems robust, but as mentioned earlier, given time these mechanical units are likely to wear or become dirty, and may then start to introduce noise while switching. For these reasons, as mentioned before, this mechanical push button switch may be best suited to the input selection function rather than output selection, and therefore the benefits of non-sequential switching are of little relevance. Ideally we'd use a non-sequential rely based switching system but could not locate a pre-exiting off the shelf module to do this at a competitive price. If we had sufficient time we could look at whether the sequential relay switching modules can easily be modified to non-sequential use but it is probably not trivial nor a good use of time.



There are a number of options for non sequential non-sequential switching which avoid the potential issues of mechanical switching and the expense of relays. That option is solid state switching and either logic ICs or microcontrollers. As discussed elsewhere, microcontrollers offer a number of other possible advantages and advanced features, but dedicated ICs would be cheaper. Our preliminary prototypes have not attempted to make use of either of these systems. We will hopefully do these evaluations at a later stage.

External connectors

There was some concern about the 3.5mm stereo jack headphone sockets we purchased for evaluation. When using some headphones, it appears that the chassis mount sockets required the plug to be pulled out a few millimetres to ensure sound could be heard in both ears. It may relate to some the fact that some of the headphones we were using had been designed for mobile phones and had four bands on the plug instead of the three used on a standard stereo jack, or it may have been poor quality sockets with inaccurate tolerances. This requires further testing with more typical headphones and maybe sourcing alternative sockets.

Another connector issue noted related to some of the RCA socket units being evaluated, the bare units not fitted to a pcb and supplied with JST headers. These bare units had solder pins that did not comply to the spacing of our vero strip boards and being flat rather than round, they would not go into the holes even when the spacing was adjusted. We managed to squeeze the pins into a shape that could be forced into our PCBs but it was fiddly and not something we can expect others to do. On this basis we would definitely recommend the pre-assembled modules with JSTs rather than the bare connectors.

The RJ45s came pre-fitted to a pcb with an eight pin header. Other formats were available but probably none more convenient. Since we are putting four bus channels down eight wires, we are constrained to four unbalanced mono pairs, and since almost all our other modules and connectors involve two channel signals and 3 pin JST connectors, we have to switch from 3 to 2 pins for each bus, thus resorting to a different cabling solution than used elsewhere in the console. Eight wire ribbon cables maybe the solution, especially if we sourced them pre-formed with the appropriate JST connectors fitted. What is certain is that a solution to this will massively reduce soldering complications and is well worth pursuing further.

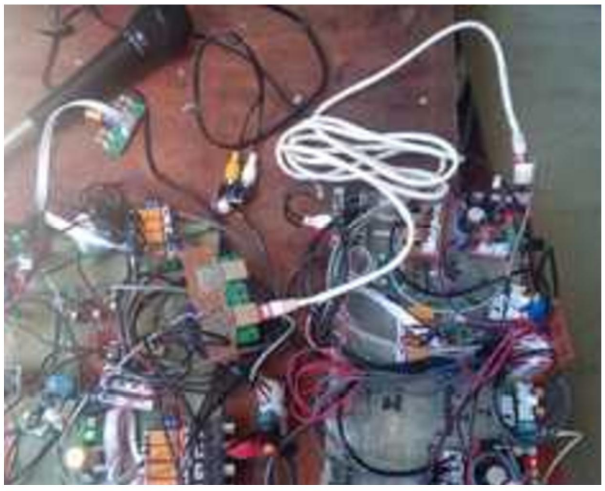
The combo XLR-1/4” jack microphone sockets proved to be fabulous, certainly a worthwhile choice compared to the other options. However it came without any pinout information and was a bugger to figure out. Good instructions for others will be essential as I wasted many hours on it.

Physical observations

It was noted that the completely assembled preliminary prototypes required a much larger footprint for the various modules and wiring than previously imagined. Certainly they could have been assembled with a more compact layout, and with connecting wires selected by required length rather than of standard sizes, there may have been less clutter. It does however seem unlikely the consoles could be made quite as tiny as first predicted, and even if it could be done, it’s probably not a good idea as it would make assembly and any subsequent repairs much more difficult. That said, we do want to find a happy compromise regarding the size as reducing the weight and volume is part of the design criteria and will mean reduced transportation costs for events.

We will get a more realistic assessment when we begin to make enclosed versions of the prototypes.

Console tests



Beyond evaluation of the individual components and modules, our initial tests of the console prototypes proved very promising. The design worked as expected, with all the signal switching elements performing well and audio levels being maintained across the system and also when shared between consoles. However, some care was required to adjust floor input level and microphone signal levels to be adequately equal at the headphones, although this is to be expected. At one stage the floor level, when received on the second console, appeared a little lower than on the first but this somehow resolved itself so may have been a connection or soldering glitch.

Noise

There was, at various stages of testing, quite a lot of noise in the form of buzzing. This did not occur when monitoring floor signals, only when listening to the mic. It was inconsistent, seemingly worsened by handling the microphone and improved or worsened when touching various cables, connectors or components. Sometimes there was very significant levels of noise, but at other times it was negligible. Given the haphazard assembly of components laid out on the table with soldering iron, power supplies, cables and microphones all criss-crossing each other, it’s hardly surprising we experienced buzzing noises at times. At the next stage of prototyping, when the components are neatly assembled in a case, we will have a much clearer idea of whether this interference is genuinely a problem.

It’s worth mentioning at this point that we have tried three different power supplies with these prototypes. The first was a standard 12v 1amp ‘wall wart’ used by coati for most of it’s equipment. This unit appeared to struggle on initial power-up to supply the power needs of the prototypes. It

would click on and off continuously if all the modules were connected at the same time, but would settle down and remain on if one module was temporarily disconnected for a few seconds then reconnected. Switching to a high output PSU solved this issue.

It may also be that different power supply units might have an effect on the buzzing issue. It was observed that it appeared to be less of a problem when we stopped using the 1 amp wall wart. Additionally, it is very likely that power supply related buzzing could be a result of us using an inverter to generate the AC power used while conducting tests (the test location is off grid). Furthermore, it is likely that the inclusion of noise suppression components such as chokes, capacitors and ferrite beads, could significant reduce future interference issues.

Cross-talk

Another form of interference observed during this early testing stage was ‘cross-talk’, with the floor signal being faintly audible on the bus channels when the consoles were linked with the cat5 daisy chain cable. This is not totally unexpected, although it was hoped that the twisted pair construction of the cat5 cables chosen for the interlink cables would have eliminated the issue. It’s worth noting that the same phenomena is often observable with the existing Coati consoles. As with the buzzing noises, it may be that the problem goes away when the prototypes as properly assembled and wires not criss-crossing in an unorganised birds nest. However, even if the issue persists, the level of the cross-talk interference observed is very low and is unlikely to cause any problem or disturbance to the users of the system. We can also play with shielded cable options.

Stage 2 : Evaluation of building prototypes into cases

Two prototypes have now been built into an enclosures. The cases for both have been cut from an aluminium plastic sandwich board and glued together with a hot glue gun. This material will theoretically provide shielding. Modules have simply been glued in place for the time being.

The first of these second stage prototypes uses all passive mechanical switching. It also uses only one headphone pre-amp module, along with a number of custom made cable splitters and combiners that allow the one amp to service to separate mono audio channels and send them to two independent headphones. I also found that I needed only one pre-amp for the microphone, using the single 5532 amplifier module.

This configuration probably represents the simplest and cheapest design. The component cost of this specific combination of components is estimated as follows:

x2 4 way rotary switches (double pole) €3.00
x1 4 way interlock push button switches €4.00
x1 ¼” jack chassis socket €0.50
x2 RJ45 boards with header pins €3.20
x8 RCA board with JST €2.50
x2 DC chassis barrel socket €0.50
x1 power switch €0.50
x3 volume ports (1 with JST, 1 bare) €3.00
x1 3 way toggle switch for floor to bus €0.80
x1 VU meter €1.00
x1 single 5532 op-amp used as pre-amp for microphone €2.00
x1 dual 5532 op-amp used as pre-amps for both headphones €4.50
x2 3.5mm chassis stereo jack sockets €1.00
x1 combo XLR/Jack socket €1.50
x24~ 3 pin JST pcb connectors €2.00
x22 cables with JST one at least one end €6.50
x16 10cm female to female wires to connect to header pins €1.00
x16 header pins €0.10
x5 knob tops €0.50
~50cm of two core red and black power cord €1.00
about half a vero strip board €1.00

Total component cost = ~€40 (not including case)

(prices based on aliexpress inc shipping, rounding up, benefits from some pro rota bulk lots)

Physical Issues

At first I attempted to assemble the components in a case measuring 20 x 15 x 4 cm but this proved too cramped. I had at first started to glue the modules on the bottom of the case, and the switches etc. on the top panel, then close the two parts. However, this proved impossible with my initial layout and even had that not been the case, getting the wires to behave when closing the top, would be very challenging. This process taught me that the best approach is to build upside down, with all the modules and switches etc being attached to the underside of the top of the console, then the bottom of the case is attached when complete. This makes assembly less complicated and would make disassembly for repair much more convenient too.

Since I could not physically accommodate my assembly into the 20 x 15 x 4 enclosure, I switched to a wedge shaped design 9cm tall at it's highest. In this configuration there was plenty of room inside.

First test of first unit by itself

The prototype was initially tested independently from the second unit. Everything worked as expected. The sound quality when listening to an input on floor was perfect, as was listening to floor sent to the various buses. Switching between input channels did not introduce any notable pops or other noises and switching through output buses with the push button interlock switch also seems clean and without issue. Additionally there was no cross-talk noted.

Picking on the microphone introduced a hum that sounds like a 50hz buzz from the inverter supplied AC power. This noise was reduced significantly when I touched the front of the console. This suggests *capacitive* coupling is occurring. There are a number of methods I can try to prevent this from occurring, such as adding a capacitor in parallel with the input into the pre-amp, and earthing all of the modules to the case.

Second unit

The second unit is of similar size to the first, a wedge measuring ~ 20 x 15 x 7cm. Again, all modules are attached on the underside of the top panel, through which are also fitted most of the switches etc. The rear, front and sides are attached to the upside-down top panel, and the various external connectors fitted.

This unit incorporates all active switching with three off the shelf four channel stereo relay boards fitted. This makes the unit considerably more cramped than the first. I deliberately installed what I consider to be the least suitable output switching module, one which cycles sequentially through the output buses using a single button.

Unlike the first unit, initially I have utilised two separate dual 5532 op-amps for the two headphones sections. This will allow for comparative evaluation of the potential to use just one, but fitting two in this test unit requires the modules to be stacked on top of each other. If figured that making it really cramped and complicated inside, with signal cables all in close proximity to each other and other parts of the unit, might help to establish whether having such a cramp design will introduce noise issues not experienced in less cramped and complicated designs.

In terms of component cost, this unit is considerably more expensive than the first.

x2 rotary controlled relay board board €28
x1 push button controlled relay board €14
x1 ¼” jack chassis socket €0.50
x2 RJ45 boards with header pins €3.20
x8 RCA board with JST (included with relay boards)
x2 DC chassis barrel socket €0.50
x1 power switch €0.50
x3 volume ports (1 with JST, 1 bare) €3.00
x1 3 way toggle switch for floor to bus €0.80
x1 VU meter €1.00
x1 single 5532 op-amp used as pre-amp for mic €2.00
x2 dual 5532 op-amp used as pre-amps for both headphones €9.00
x2 3.5mm chassis stereo jack sockets €1.00
x1 combo XLR/Jack socket €1.50
x24~ 3 pin JST pcb connectors €2.00
x26 cables with JST one at least one end €3
x3 knob tops €0.30Next
~50cm of two core red and black power cord €1.00
about half a vero strip board €1.00

Total component cost = ~€72 (not including case)

(prices based on aliexpress inc shipping, rounding up, benefits from some pro rota bulk lots)

The higher cost is mostly down to the relays, which cost more than the entire component cost of the first unit. There’s also the extra pre-amp. However, despite being significantly more complex than the cheaper unit, there was actually less soldering involved since the main switching elements all featured JST connectors. They also came with cables and RCA sockets, offsetting some of the price difference. That is not to say that I’d recommend the relay modules on this basis, it’s just good to be aware that the cheapest combination of components may not be the simplest or quickest to assemble.

Second unit individual tests

The basic functions all worked as expected with the exception of the three position switch that allows the user to switch off the mic and instead pass the floor signal to their selected output channel. I used a three way switch so that the middle position provides a microphone off function but I must have connected it incorrectly as the middle position still carried the mic signal (it works find on the first unit).

The LEDs that indicate channel selection provided a convenient way to observe power was present (only the VU meter provides this information on the first unit). Unsurprisingly perhaps, this unit did seem to be noisier than the firsr, and the hum appeared to be reduced much less by simply touching the case. The sequential channel output was super annoying to use. The headphone output seemed a little more powerful than the first unit, but not significantly so.

Testing both prototypes together

Noise grew much worse with the two units chained together and touching the case of one or both units did not provide such significant reduction. The noise only relates to whichever bus channels are being used with the microphone, the floor channel or relayed floor channels are entirely without noise. I haven't yet tried to incorporate any noise reduction strategies such as adding low pass filters etc. I have a very limited range of components available to try different capacitor values at this time. I will try playing earthing the modules to the case. I'll also try to power the units with 12DC from battery to establish for certain whether the noise is an AC hum.

The tests revelled notable cross-talk that manifested as being able to hear the floor signal on all channels at much reduced levels. It was not annoying loud but definitely there. Interestingly it didn't appear that the cross-talk was a result of the console interlink cable. Instead it appeared that the interference was occurring earlier. I don't current have access to an oscilloscope to use in attempt to figure out at which point the cross-talk is being generated.

It's worth noting that by turning the level down on the device provided my simulated floor PA, the cross-talk almost disappeared entirely and the headphone amps had enough headroom to compensate for the lower level floor signal. It's entirely possible that the cross-talk is actually a non issue in this context. However, it may be that when many more consoles are chained together, the floor level would need to be raised higher, perhaps exacerbating the issue. I can't explore this further with only a few consoles.

Finally, I tested the situation were both consoles attempted to use the same output bus. The results were reassuring – basically they get combined if similar levels. When floor was being relayed, it appeared to win over a microphone, but I guess that's dependent on levels also. There was a moment when it felt like the floor relay had somehow locked the channel as even when I muted the source, I still could not hear the microphone until I released the floor relay switch on the other console. But performing these tests by myself was difficult and I may have imagined it so I recruited a volunteer and tried again. Inexplicably, there was definitely some weird locking of audio going on. I really cant explain it at all! Magic but not usefully so.

I also tried to check what listeners might experience when the second unit, the one with the sequential output selector, 'passed through' the channel they were listened to. Surprisingly there was little discernable interruption at all, unless the floor was being relayed, in which case, yeah, there was a brief but intolerable interjection, the very reason why sequential switching on the output selection should be avoided.

Next steps

The priority is definitely to work on the mic noise issue. Unfortunately I may not have the range of components to work on this until my turn to Europe, and certainly will not have access to an oscilloscope until I do. There are a few things I can try in the meantime and we will see if they progress things or at leat point towards a solution.

I will probably return to pre-amp module evaluation to confirm my gut feeling about sticking to the 5532 based amps. I'd like to retest the mic pre-amp modules, especially the one with the built in compressor, to see if there is any improvement on the noise issue. If they prove usable then I might be able to build a third boxed prototype as I could free up two amp modules currently being used as mic-pre amps. A third prototype would enable more representative testing, and also enable me to start to develop the layout of components within the case, as well as the lessons learned about the positioning of the controls and connections.