Making a nEXO Scale Model HAT

This is a guide to making your very own HAT for the nEXO scale model. Let’s begin!

The schematic for the hat is on the GitHub, here is a picture of it:

A diagram of a computer

Description automatically generated

The thought process behind is to have the LEDs connected in parallel to each other on the collector side of the transistor. The parallel components are shown in the red boxes in the above figure. The transistors are found in the IC chip ULN2803A.

Each LED needs it own resistor to prevent thermal runaway from burning out all the LEDs. In addition, each colour of the RGB LED requires a different voltage, so a different resistor is needed for each colour. To not be beholden to the actual model while testing the code, indicator LEDs are included in series with the GPIO pins going into the base of the transistors.

The resistor values used are: 75 Ohm for the green LED, 130 Ohm for the red LED, 100 Ohm for the blue LED, and 91 Ohm for the wall and floor LEDs. The indicator lights also need a resistor soldered in series with them, the value of this resistor is somewhat arbitrary it just needs to be large enough to limit the current flowing through the LED. For the HATs assembled at McGill, they all have a 1000 Ohm resistor soldered in series with them. Note as well that the indicator lights are present for any debugging needs, and so their colour is also arbitrary. At McGill, we took care that the green GPIO pin has a green light and so on, but the colours of the wall and floor LEDs have no significance.

Here are the steps to assembling the HAT.

Begin by soldering the socket for the IC transistor circuit on the 6th pin from the left side over, as shown in the image below.

A close up of a circuit board

Description automatically generated

Next, solder the wires to make the connections to the relevant areas on the board. Note that the top left corner of the socket needs to be connected to ground, so a small jumper wire is used to connect that line to ground.

A white circuit board with yellow and blue wires

Description automatically generated

Connection to ground

Once these wires are soldered in place, it is time to add the resistors. First add the resistors for the green, red, and blue colours of the RGB LED. These resistors are 75 Ohm, 130 Ohm, and 100 Ohm respectively.

A close up of a circuit board

Description automatically generated

Now, add the resistors for the wall lights.

A circuit board with many small colored wires

Description automatically generated

Notice here that two resistors are on the same column despite each resistor needing to go to a unique LED. To prevent this, the trace connecting the column needs to be scratched off. This can be done with an exacto knife or any other sharp abrasive. Make sure to wear safety goggles when doing this step. We will come back to this step so for now, carefully mark the trace that needs to be erased.

Next, we add the resistors that go to the floor lights.

A close up of a circuit board

Description automatically generated

Make sure that these all connect to the blue wire and all bridge to a unique column.

Next, solder on the 1k resistors used for the indicator LEDs. Make sure that one end of the resistor is connected to the column with the wire coming from the GPIO pin and the other end to an unused column.

A circuit board with many small colored objects

Description automatically generated with medium confidence

Now we add the indicator lights for the green, red, and blue pins. Connect the cathode (longer leg on the light) to the resistor on the unused column and the anode (the shorter leg) to ground.

A close up of a circuit board

Description automatically generated

Next add the last two lights to indicate that the wall and floor GPIO pins are working, once again, the colour of the lights is arbitrary.

A circuit board with many different colored lights

Description automatically generated

Finally, we connect the wires that go to the block terminal. Make sure that the wires connect to the ends of the resistors that are in the unique columns, so that the resistors are in series with the connection at the block terminal. It is also during this step that we will remove the traces that need to be erased.

A white circuit board with gold and silver circles

Description automatically generated

This is what the underside of the HAT should look like with the traces erased. Here a few more traces are removed, specifically the ones going from the indicator lights to the IC as a precaution against accidentally activating the transistor when the indicator lights are turned on, but it shouldn’t need to be done.

You should now have a fully functioning HAT to control the LEDs in your nEXO scale model! The next steps should be wiring the lights to the terminal block on the model and connecting the wires from the HAT to the terminal block in the RPI4 box. These are then connected via a 15 pin cable that must have 15 individual wires so that each connection goes through independently. A regular VGA cable will not work as several of the pins are tied together.

If you have any questions, do not hesitate to send them to Julien Hacot-Slonosky at [julien.hacot-slonosky@mail.mcgill.ca](mailto:julien.hacot-slonosky@mail.mcgill.ca)