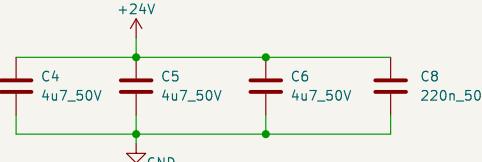


## 24V to 5V

### Input Capacitor

A minimum of  $10\ \mu\text{F}$  of ceramic capacitance is required on the input of the LMR33630. This must be rated at least the maximum input voltage that the application requires; preferably twice the maximum input voltage. This capacitance can be increased to help reduce input voltage ripple and maintain the stability of the regulator. It is recommended to place the input capacitor as close as possible to the input, as close a possible to the regulator. This provides a high frequency bypass for the control circuits internal to the device. For this example a  $4.7\ \mu\text{F}$ ,  $50\text{-V}$ , X7R (or better like COG) ceramic capacitor is chosen. Internal to the device, the  $220\ \text{nF}$  must also be rated at  $50\text{V}$  with an X7R or COG dielectric.

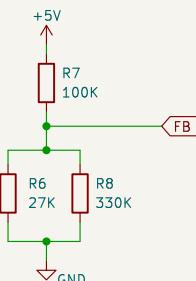
Please mind that the input capacitor should have a smaller footprint to have smaller ESL. <https://www.signalintegrityjournal.com/articles/1589-the-myth-of-three-capacitor-values>



### Reference Voltage

Output Voltage Set-Point:  
 $R1 = R2 / (V_{Out}/V_{IN} - 1)$   
 $R1 = 100k / (5V - 1V)$   
 $= 25k$

Please mind:  
 $R2$  is recommended to be app.  $100\text{k}\Omega$   
For  $R1 = 24.9k$  is chosen as recommended in the datasheet.  
 $27k || 330k = 27k * 330k / (27k + 330k)$   
 $= 24.958$



### Output Filter

**Inductor Selection**  
The parameters for selecting the inductor are the inductance and saturation current. The inductance is based on the desired peak-to-peak ripple current and is normally chosen to be in the range of 20% to 40% of the maximum output current. Experience shows that the best value for inductor ripple current is 30% of the maximum load current. Note that when selecting the ripple current for applications with much smaller maximum load than the maximum available in the device, the inductor core could be used. Equation 6 can be used to determine the value of inductance. The constant K is the percentage of inductor current ripple. For this example,  $K = 0.3$  was chosen.

$$L = ((V_{IN} - V_{OUT}) \times (V_{OUT} / V_{IN})) / ((f_{SW} \times K \times I_{OUT,PEAK}))$$

$$= (24V - 5V) \times (5V / 24V) / (400\text{kHz} \times 0.3 \times 2.5A)$$

$$= 14.34\text{uH}$$

Therefore we take the next available standard inductor value of  $15\text{uH}$ .

For this example, a  $\Delta V_{OUT} \leq 250\text{ mV}$  for an output current step of  $\Delta I_{OUT} = 2\text{ A}$  is required. Equation 6 gives a minimum value of  $52\text{ uH}$  and maximum ESR of  $0.4\text{ mOhm}$ .

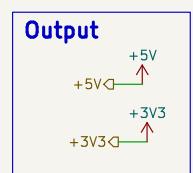
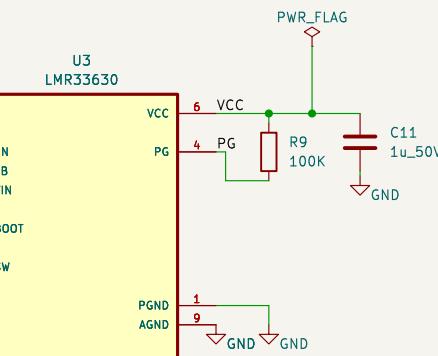
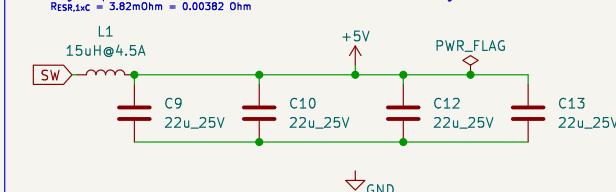
More output capacitance can be used to improve the load transient response. Ceramic capacitors can easily meet the minimum ESR requirements. In some cases, an aluminum electrolytic capacitor can be placed in parallel with the ceramics to help build up the required value of capacitance. In general, use a capacitor of at least  $10\text{ V}$  for output voltages of  $3.3\text{ V}$  or less and a capacitor of  $16\text{ V}$  or more for output voltages of  $5\text{ V}$  and above.

For the capacitor we use  $4 \times 25\text{uF}$  X5R  $\pm 10\%$  1206 Multilayer Ceramic Capacitors MLCC (CL31A226KAHNNNE). If you check the specifications under <https://product.samsunsgsm.com/mlcc/CL31A226KAHNNNE>.

You can find, that the DC Bias at  $5\text{ V}$  DC is  $-37.96\%$  of the original capacity, so

$$C_0 = 4 \times 22\text{uF} \times 0.62 = 54.56\text{uF}$$

To find out the  $R_{SS}$  of the capacitor we can check the graph given in the above link and check the ESR value at the self-resonant frequency where the impedance  $|Z|$  is minimal. This is the value that they give with the capacitor they took in the datasheet. The link to the capacitor of the datasheet can be found here: [https://product.tdk.com/en/search/capacitor/ceramic/mlcc/info?part\\_no=C3216X5R0J476M160AC](https://product.tdk.com/en/search/capacitor/ceramic/mlcc/info?part_no=C3216X5R0J476M160AC). Following this procedure, the ESR value for ONE CL31A226KAHNNNE is something like:



Sheet: /Power Stage/  
File: power\_stage.kicad\_sch

### Title:

Size: A4 Date:

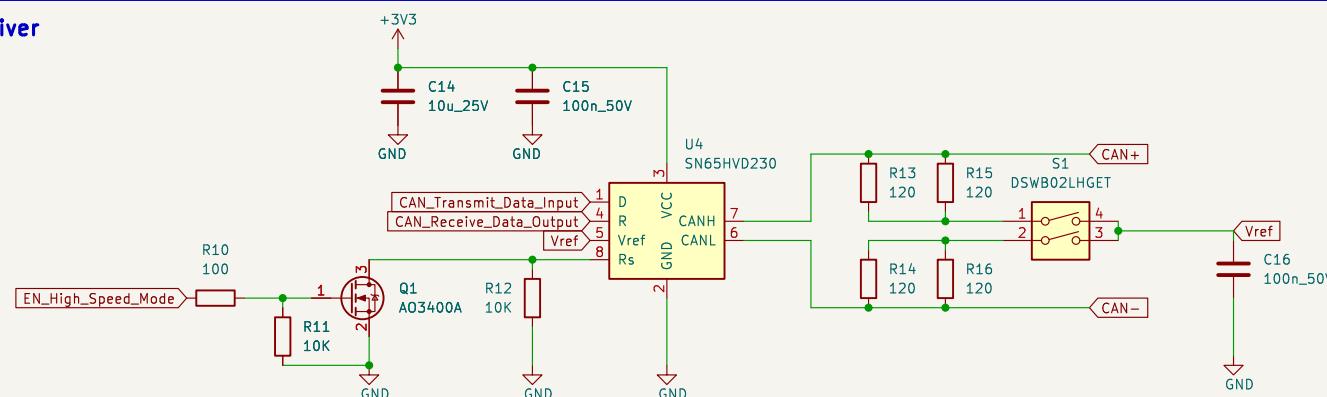
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1 2 3 4 5 6



### CAN Transceiver



Sheet: /CAN\_Communication/  
 File: CAN\_Communication.kicad\_sch

### Title:

Size: A4 Date:  
 KiCad E.D.A. 8.0.6

Rev:  
 Id: 3/68

1 2 3 4 5 6

A

A

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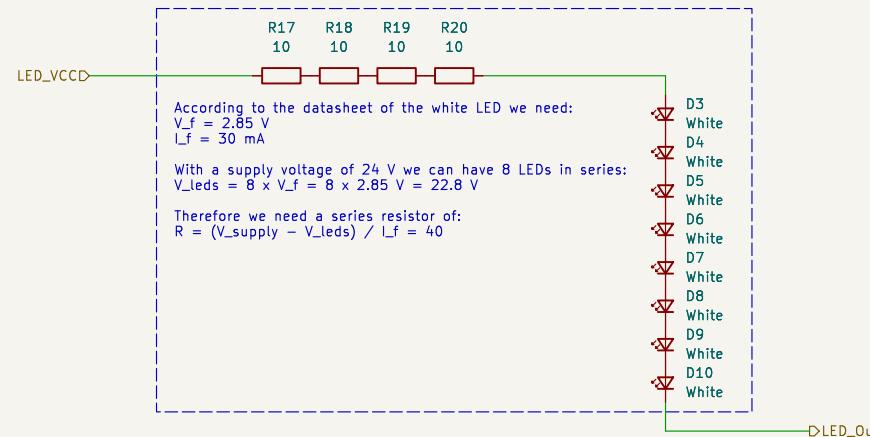
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Sheet: /LED\_Control/8xLED\_White1/  
File: 8xLED\_White.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 4/68

A

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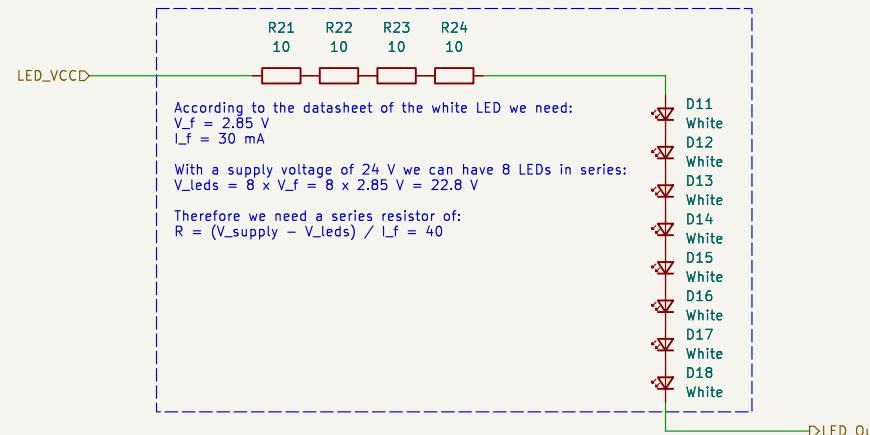
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Sheet: /LED\_Control/8xLED\_White2/  
File: 8xLED\_White.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 5/68

A

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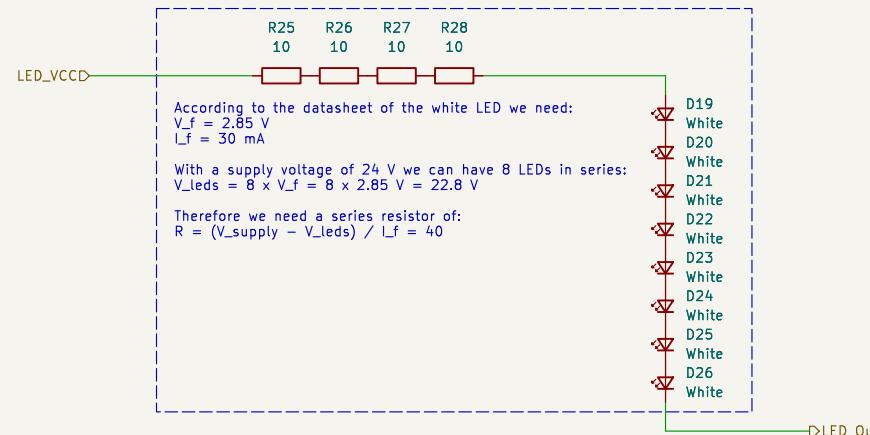
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File: 8xLED\_White.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

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Id: 6/68



A

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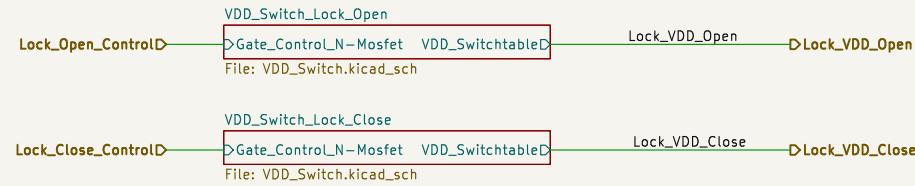
B

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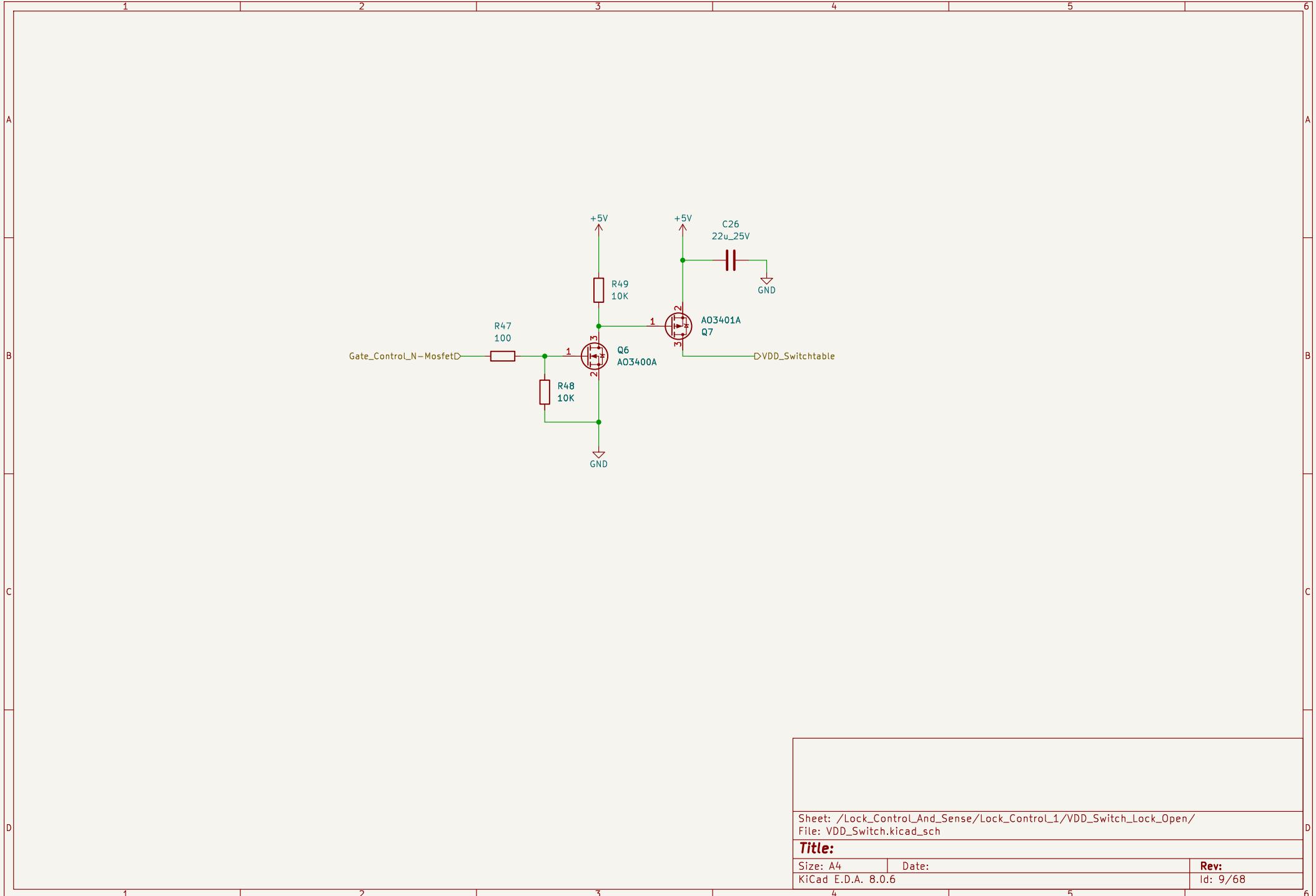


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File: Lock\_Control.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 8/68





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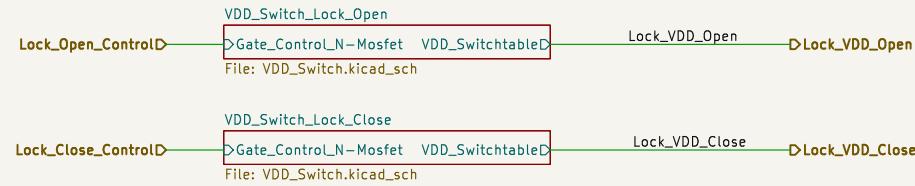
B

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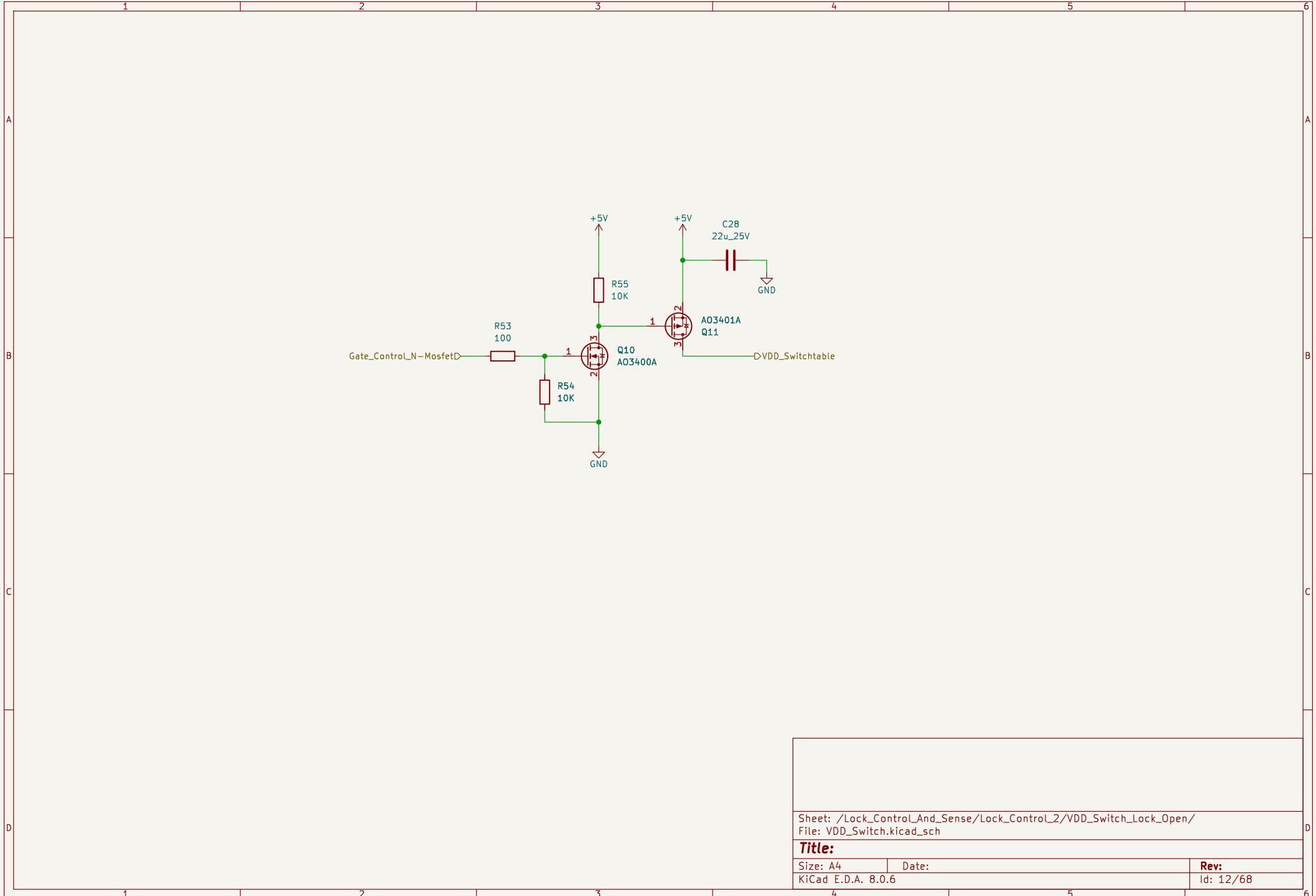


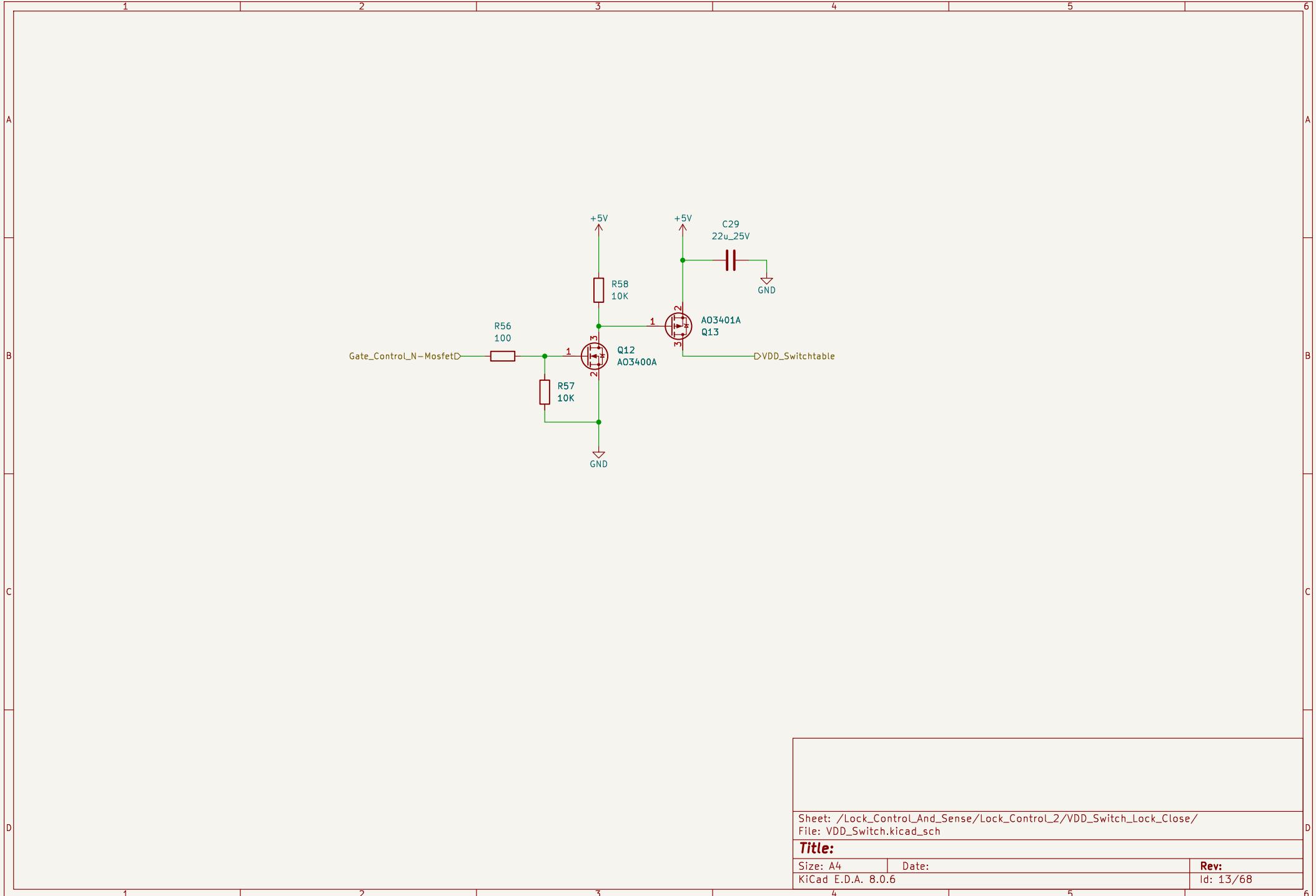
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KiCad E.D.A. 8.0.6

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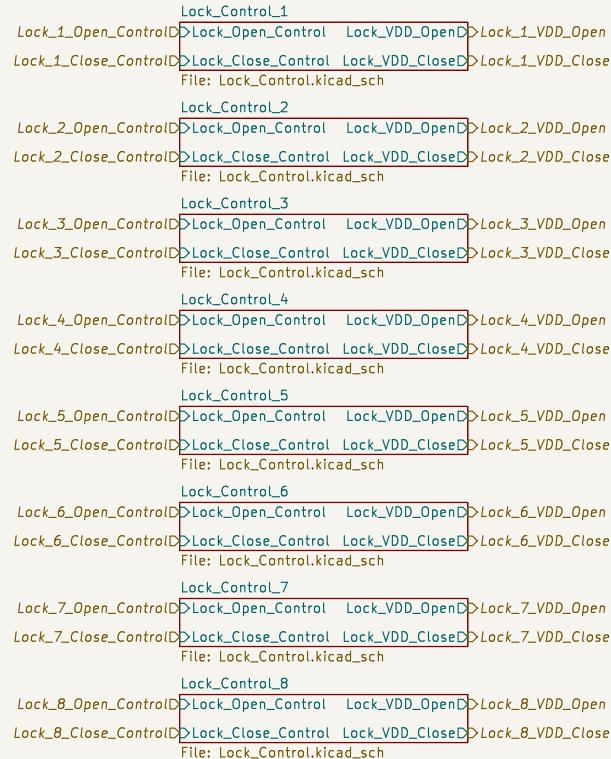
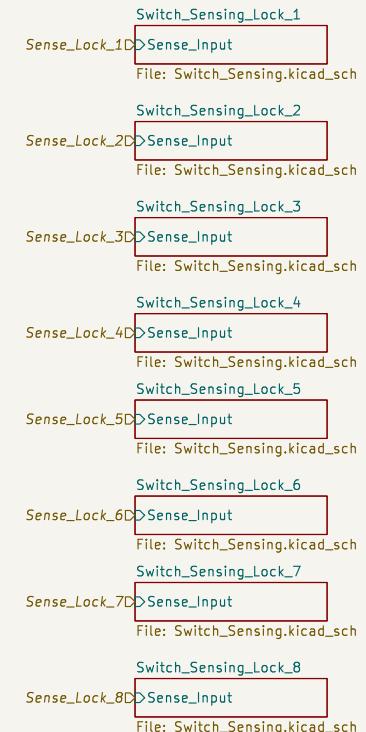


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**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

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Id: 14/68

**Lock Control****Switch Sensing**

Sheet: /Lock\_Control\_And\_Sense/  
File: Lock\_Control\_And\_Sense.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

Rev:  
Id: 15/68

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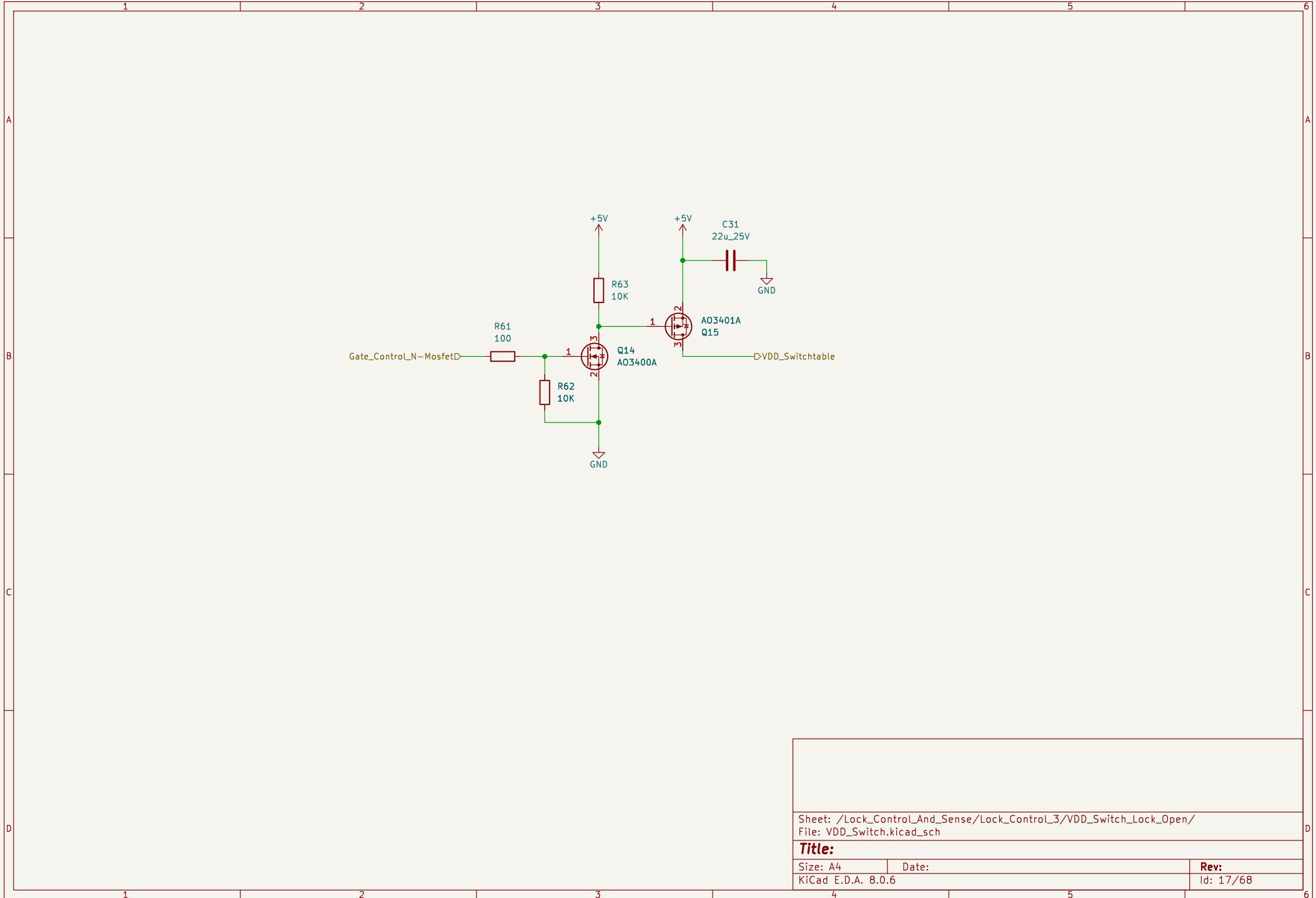


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**Title:**

Size: A4 | Date:  
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**Rev:**  
Id: 16/68

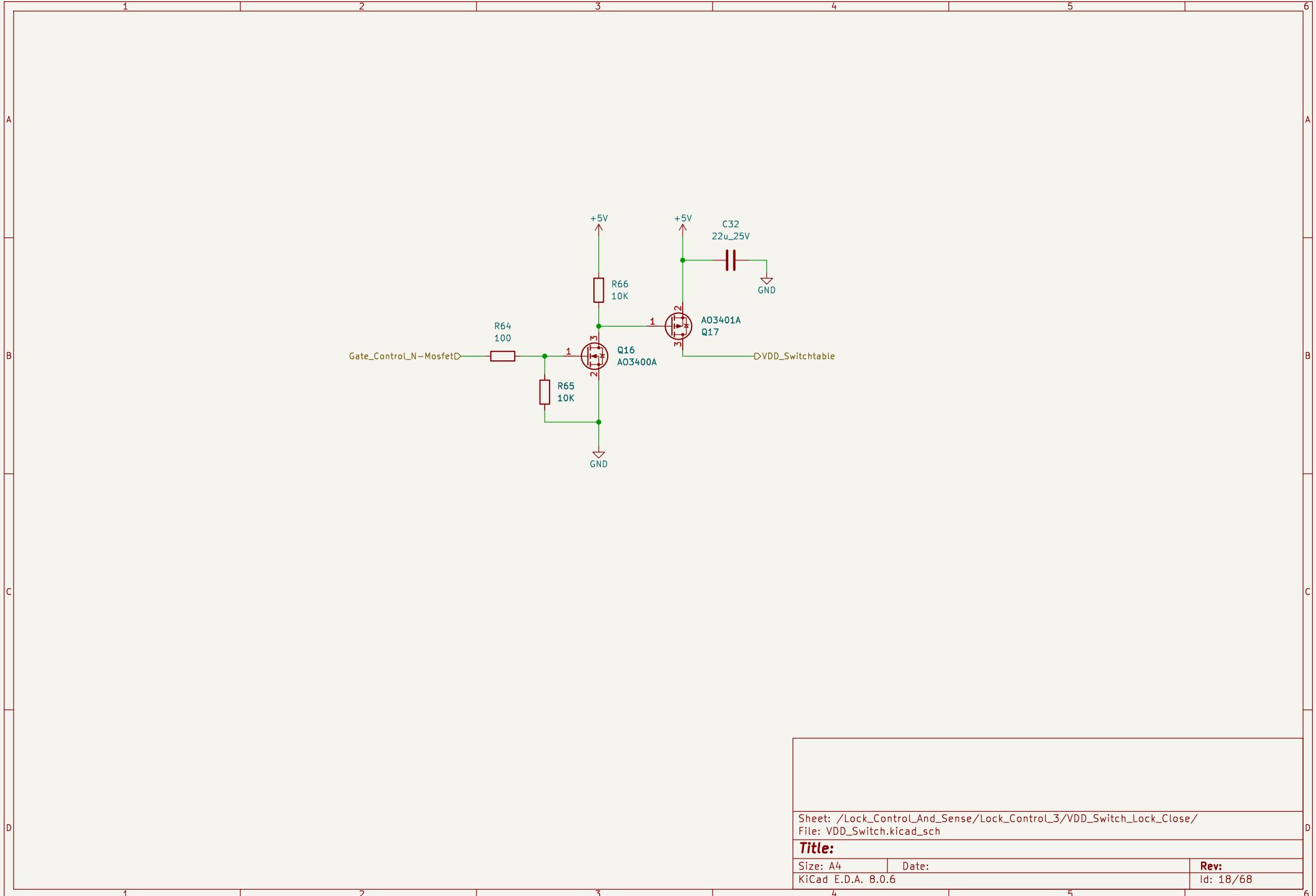


Sheet: /Lock\_Control\_And\_Sense/Lock\_Control\_3/VDD\_Switch\_Lock\_Open/  
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**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 17/68



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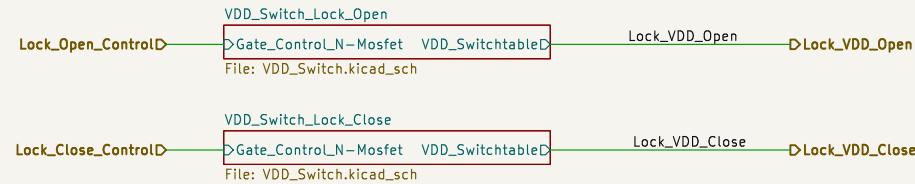
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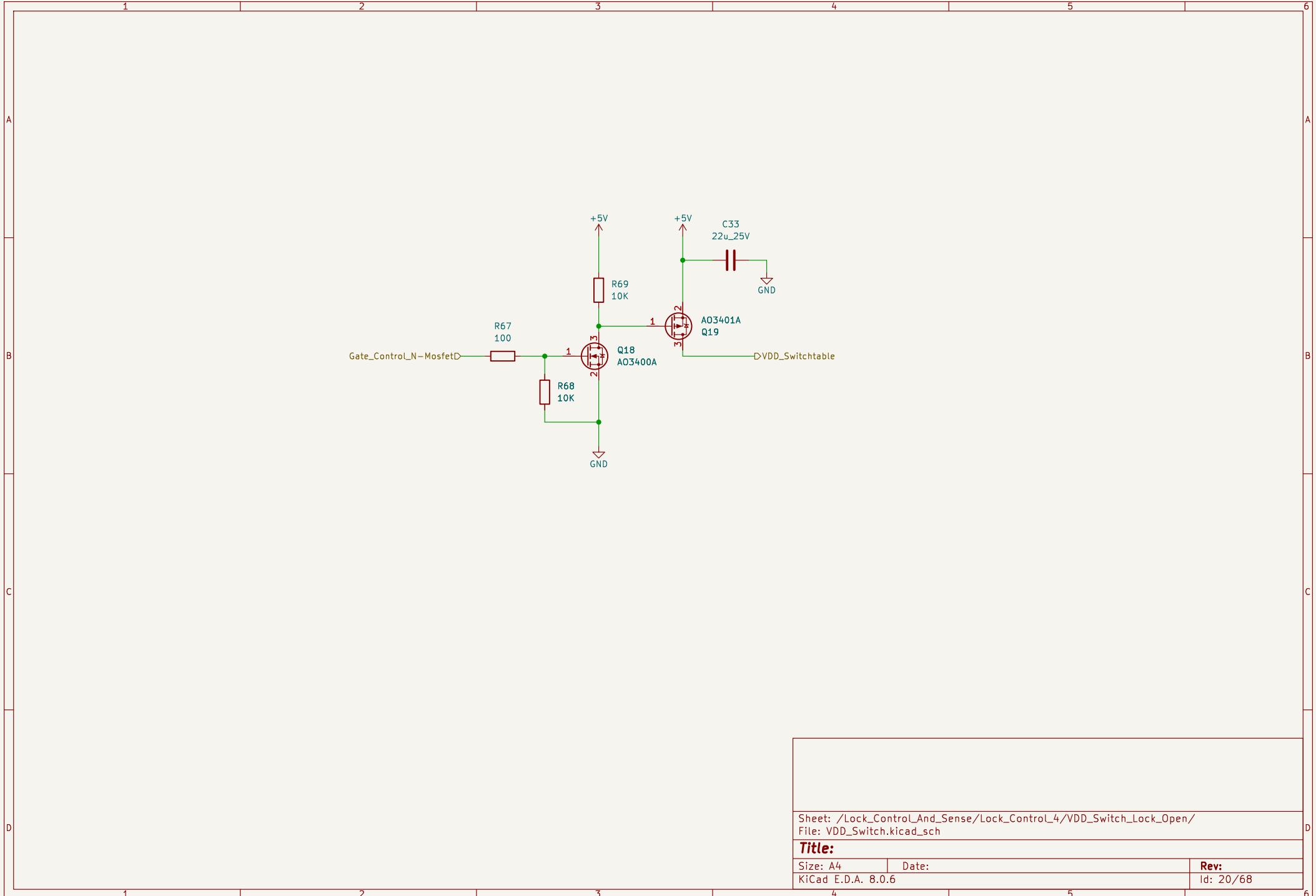


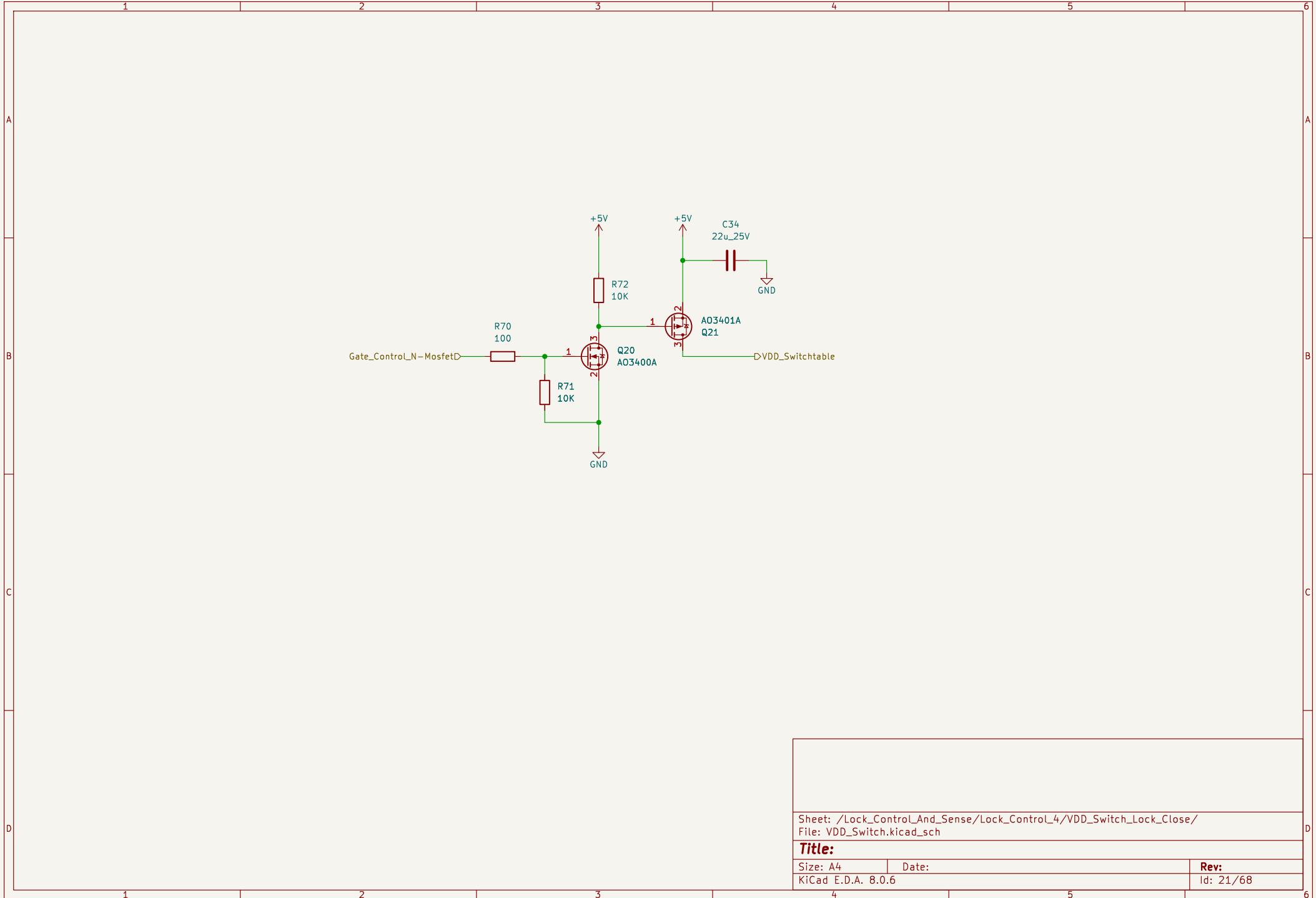
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**Title:**

Size: A4 | Date:  
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Rev:  
Id: 19/68





Sheet: /Lock\_Control\_And\_Sense/Lock\_Control\_4/VDD\_Switch\_Lock\_Close/  
File: VDD\_Switch.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 21/68

A

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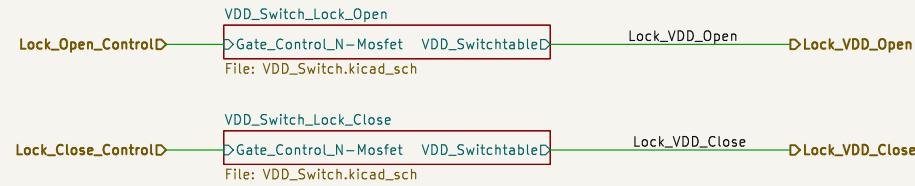
B

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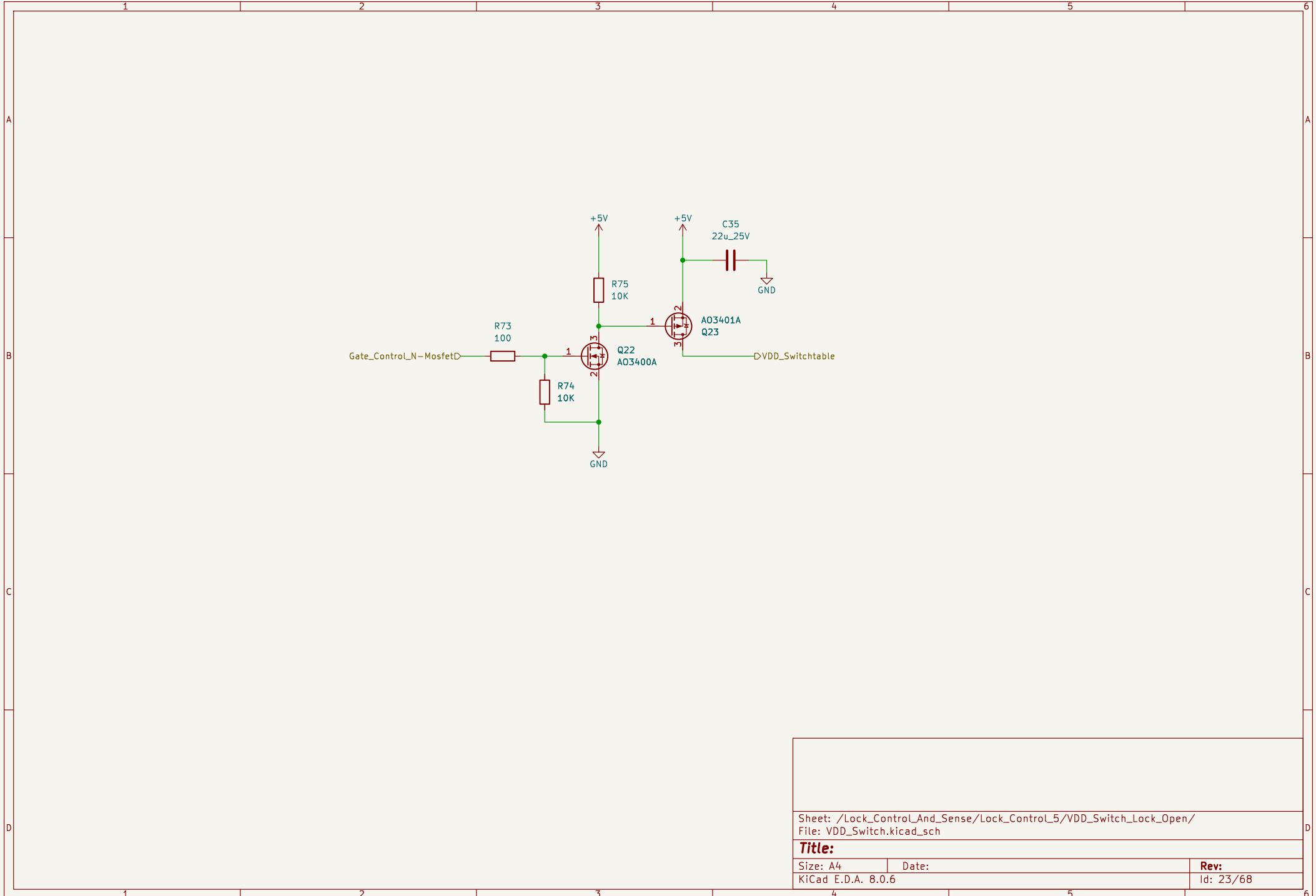


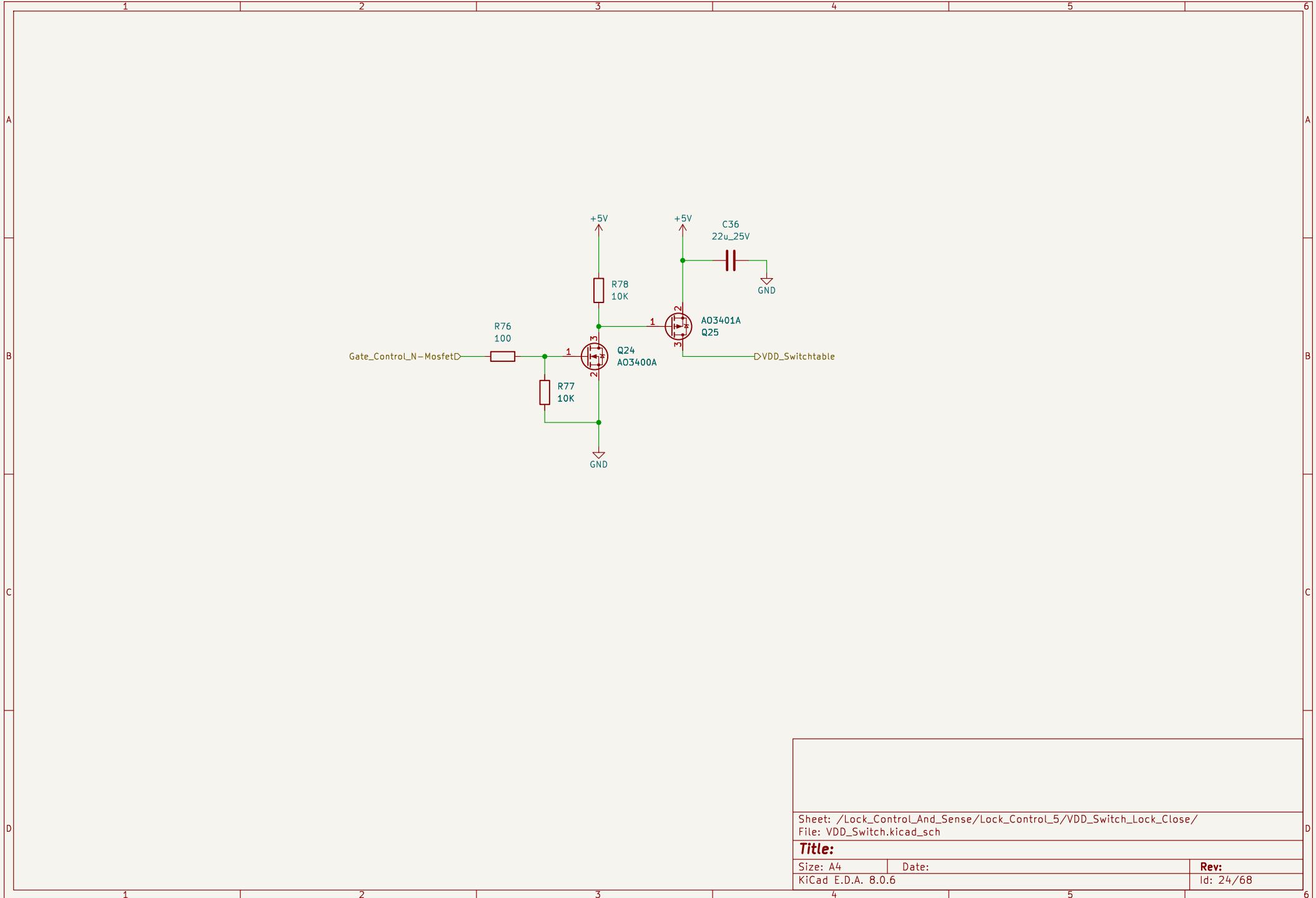
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**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

Rev:  
Id: 22/68





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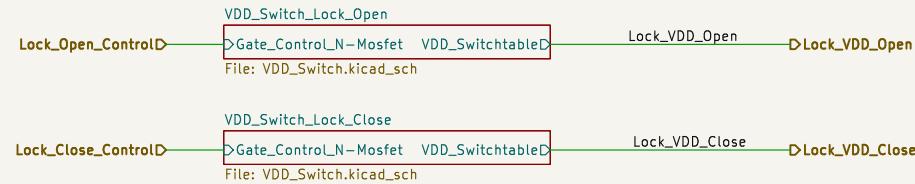
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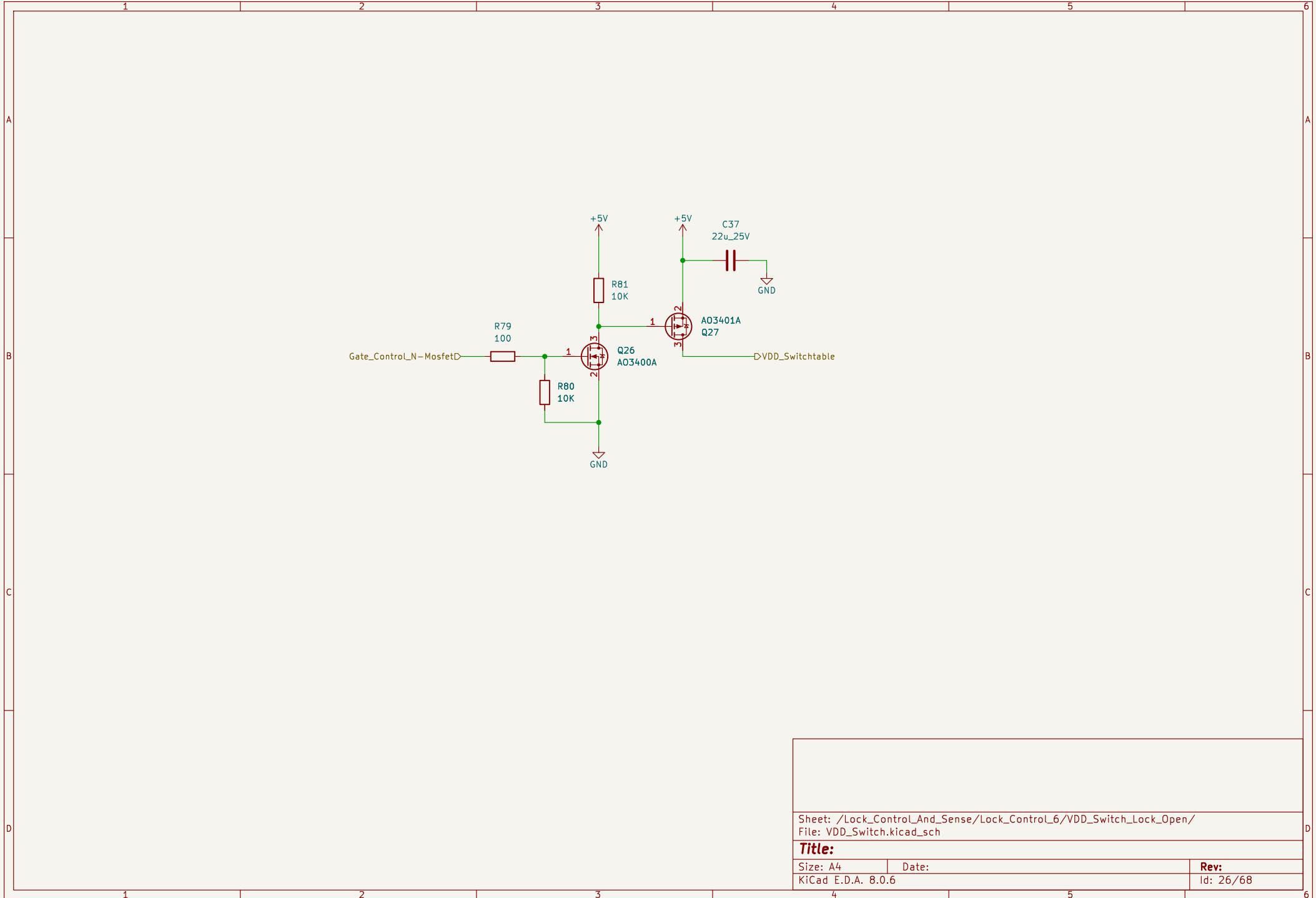


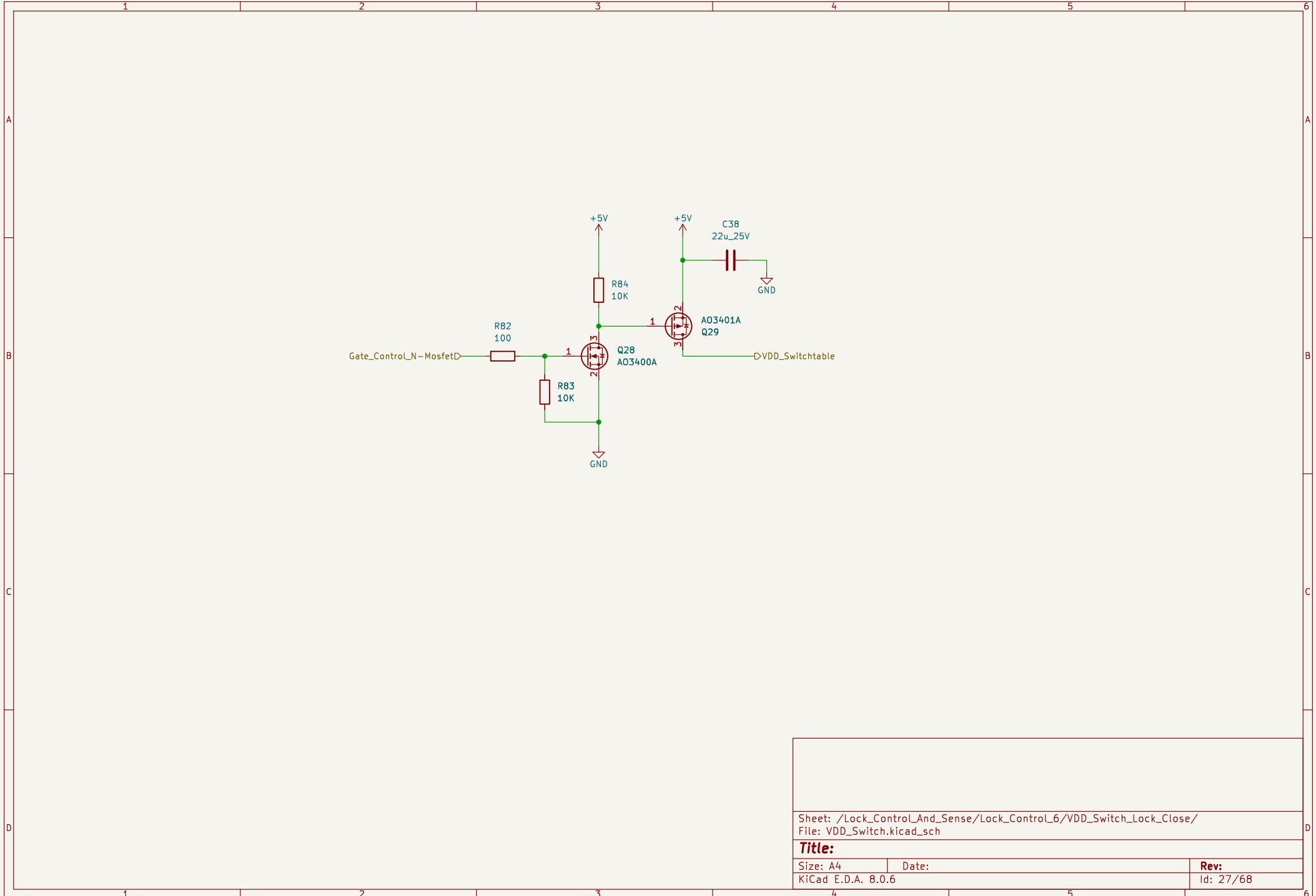
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**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 25/68





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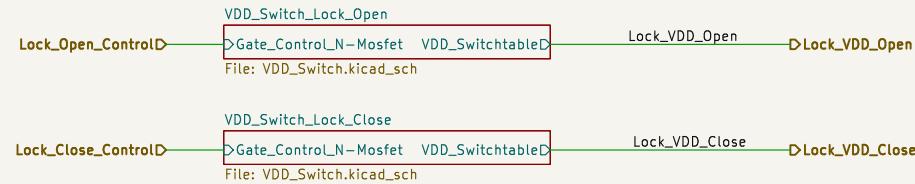
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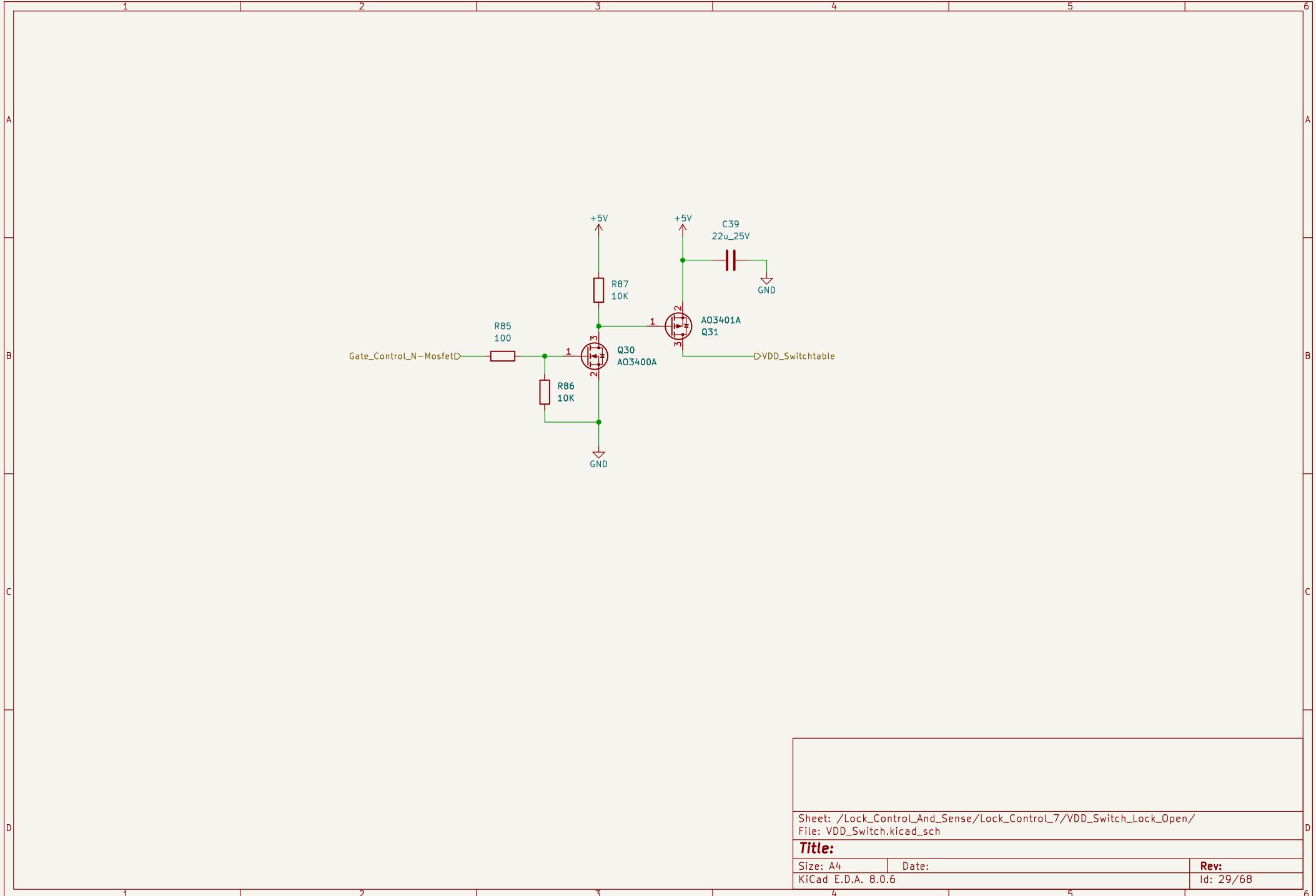


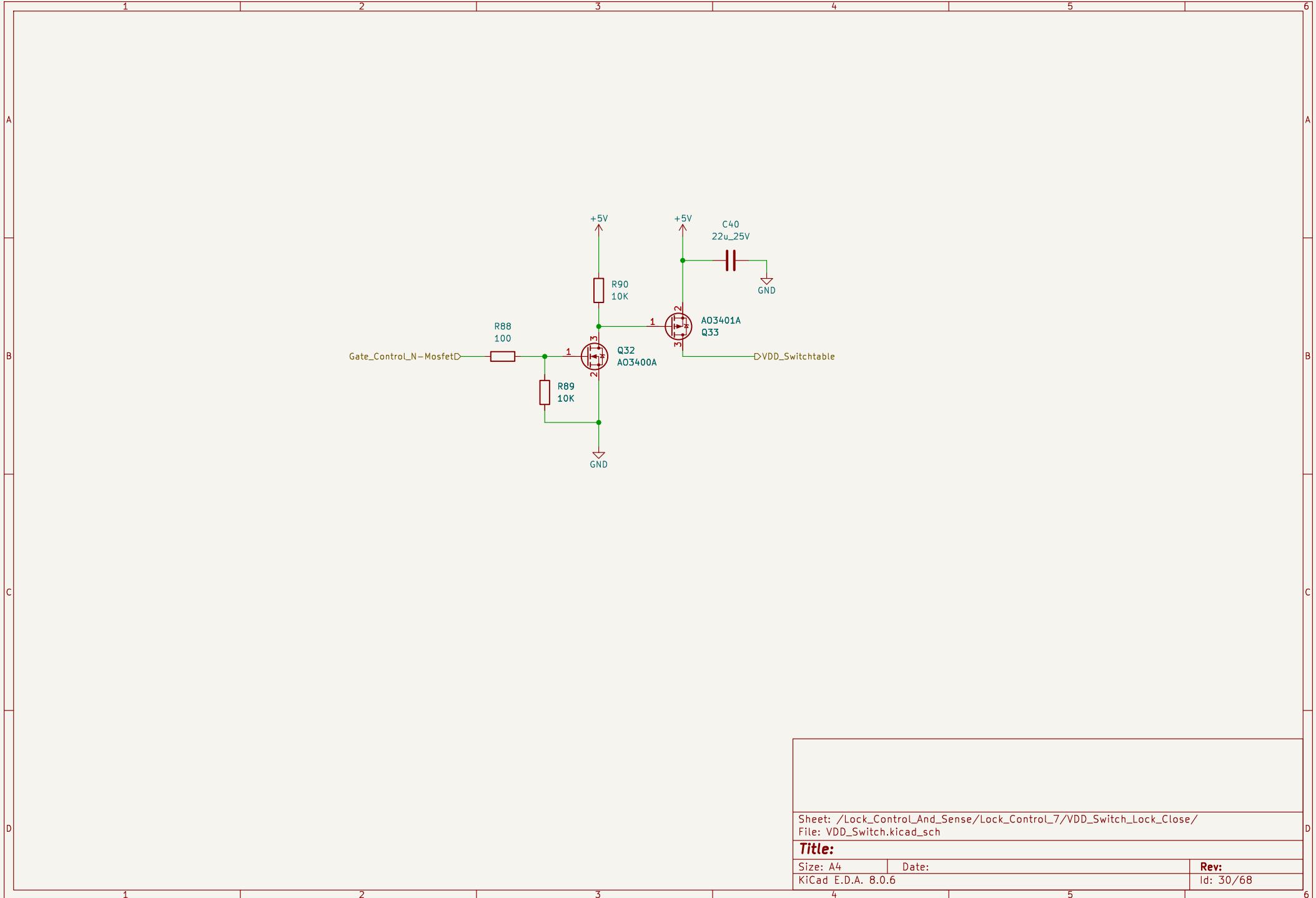
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File: Lock\_Control.kicad\_sch

**Title:**

Size: A4 | Date:  
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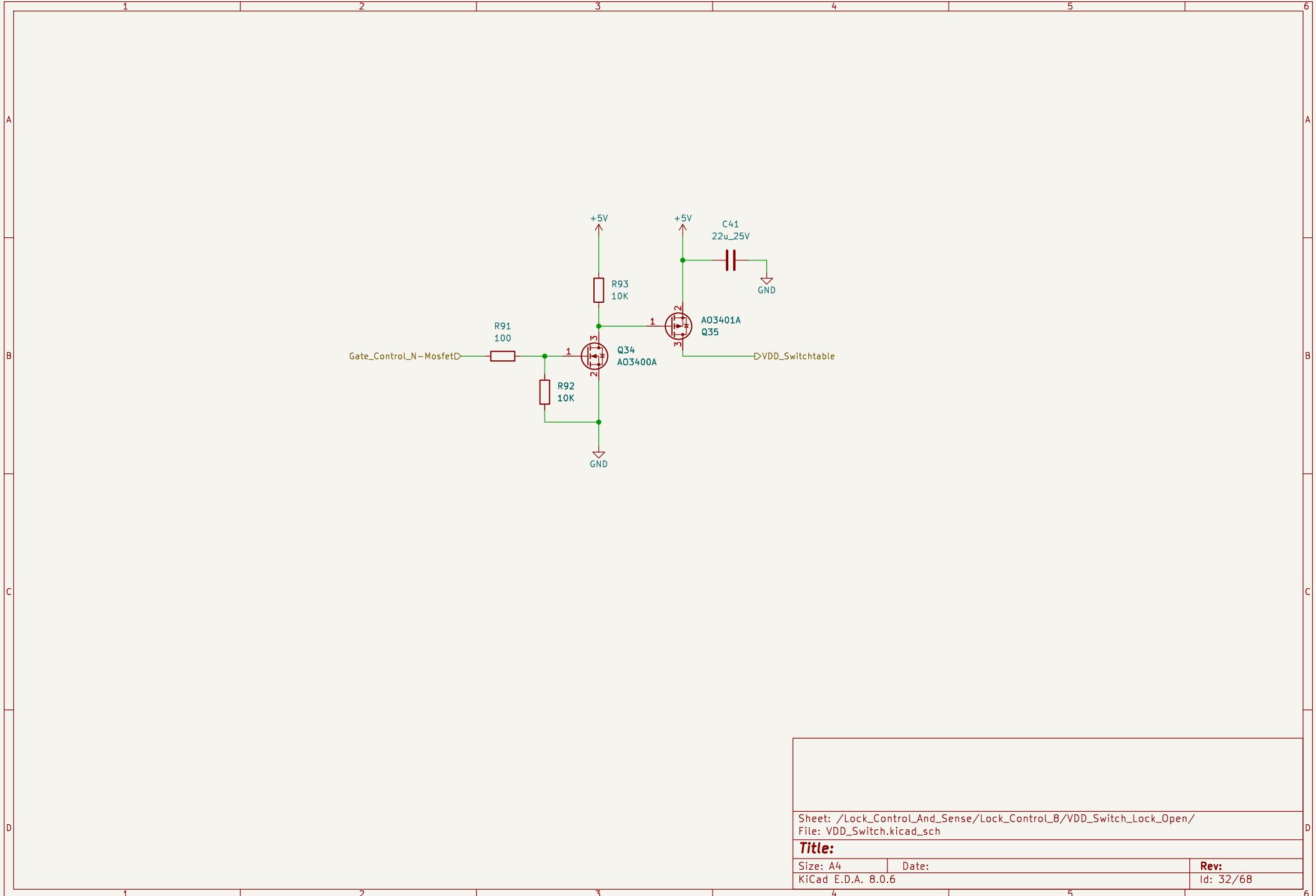


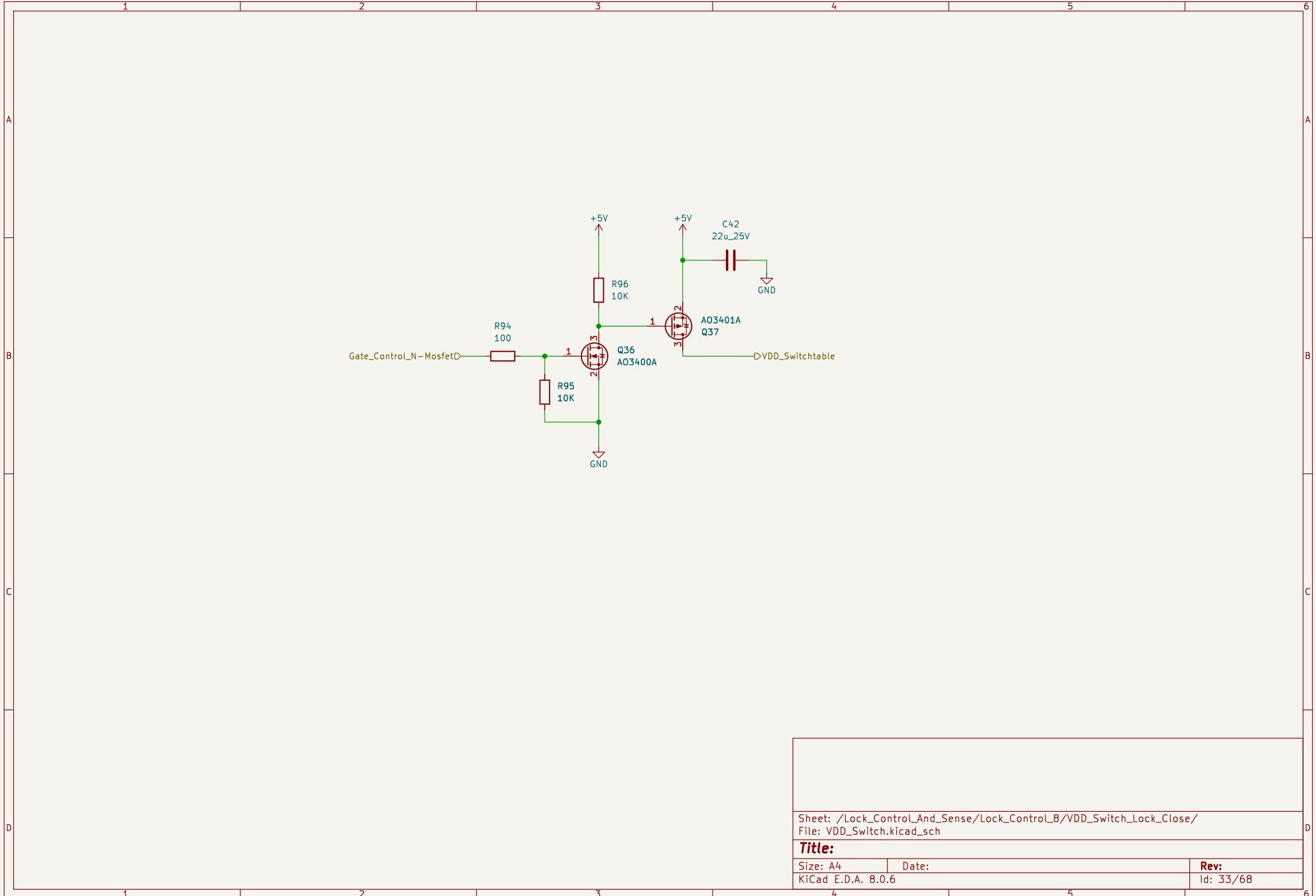
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Rev:  
Id: 31/68





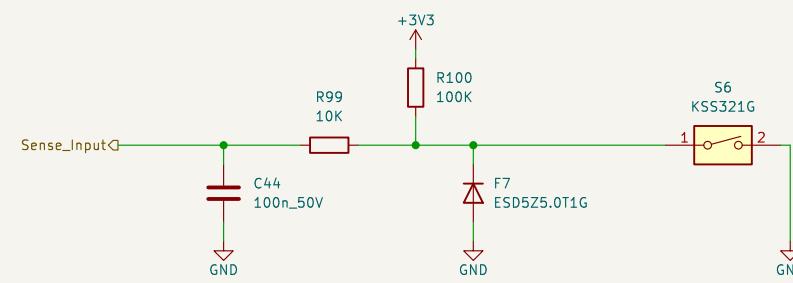


Sheet: /Lock\_Control\_And\_Sense/Switch\_Sensing\_Lock\_2/  
File: Switch\_Sensing.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

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Id: 34/68



Sheet: /Lock\_Control\_And\_Sense/Switch\_Sensing\_Lock\_3/  
File: Switch\_Sensing.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 35/68



Sheet: /Lock\_Control\_And\_Sense/Switch\_Sensing\_Lock\_4/  
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**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 36/68

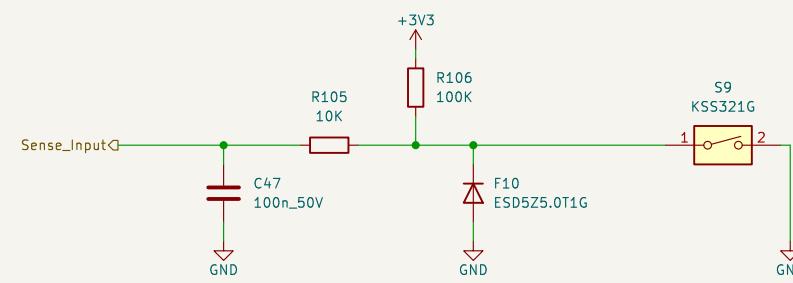


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File: Switch\_Sensing.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 37/68



Sheet: /Lock\_Control\_And\_Sense/Switch\_Sensing\_Lock\_6/  
File: Switch\_Sensing.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 38/68



1 2 3 4 5 6

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Sheet: /Lock\_Control\_And\_Sense/Switch\_Sensing\_Lock\_7/  
File: Switch\_Sensing.kicad\_sch

**Title:**

Size: A4 Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 39/68

1 2 3 4 5 6

A

A

B

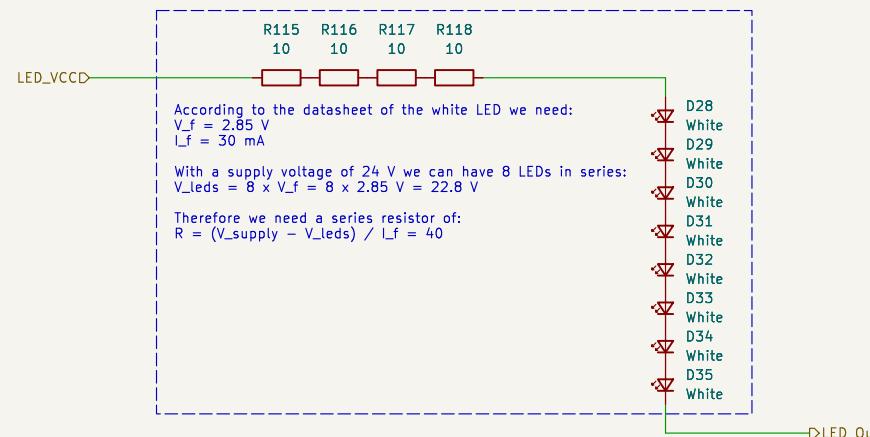
B

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Sheet: /LED\_Control/8xLED\_White/  
File: 8xLED\_White.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 39/68

1 2 3 4 5 6

A

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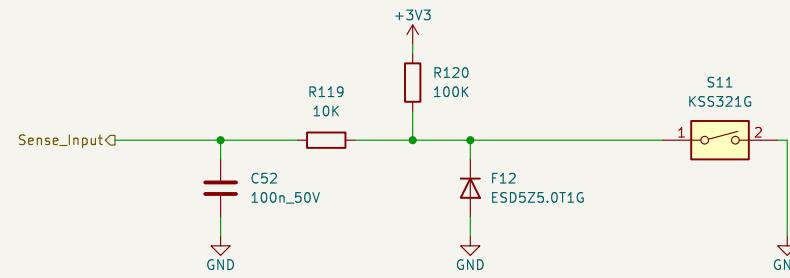
B

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Sheet: /Lock\_Control\_And\_Sense/Switch\_Sensing\_Lock\_8/  
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**Title:**

Size: A4 Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 40/68

1 2 3 4 5 6

A

A

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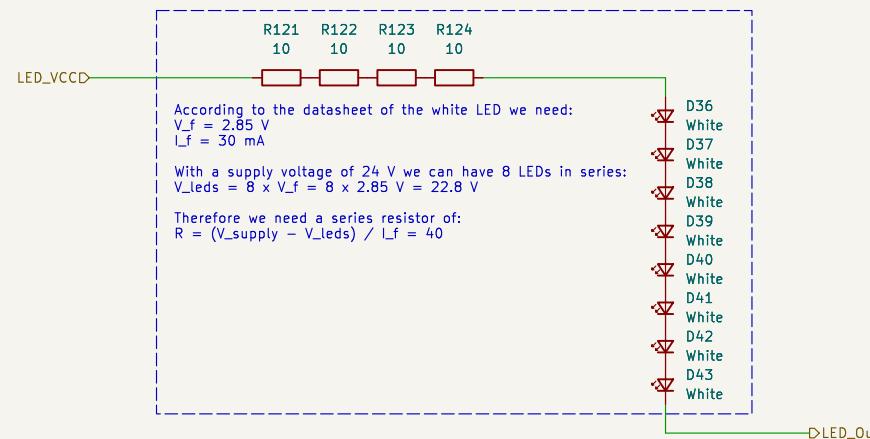
B

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Sheet: /LED\_Control/8xLED\_White4/  
File: 8xLED\_White.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 41/68

A

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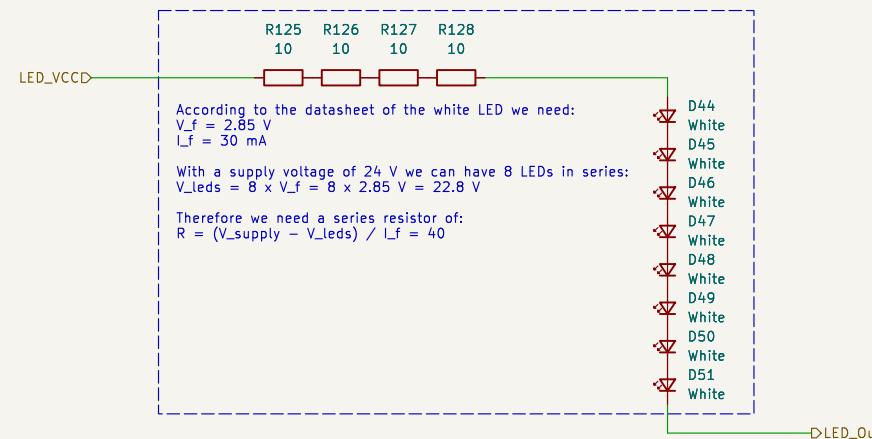
B

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Sheet: /LED\_Control/8xLED\_White5/  
File: 8xLED\_White.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 42/68

A

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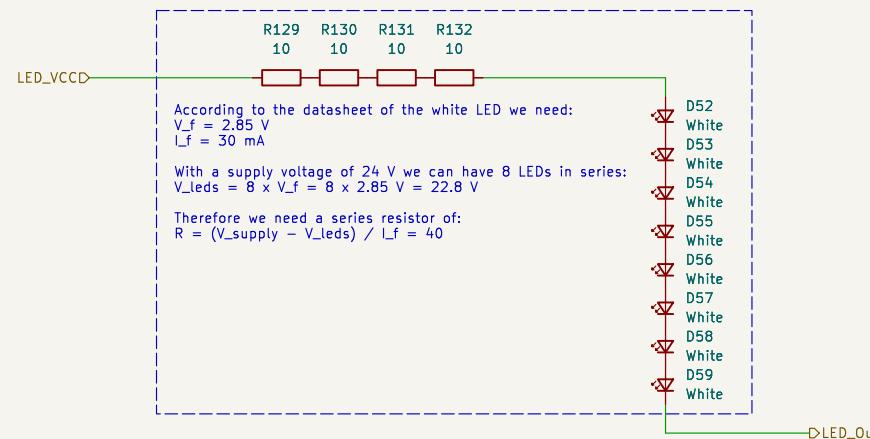
B

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File: 8xLED\_White.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 43/68

A

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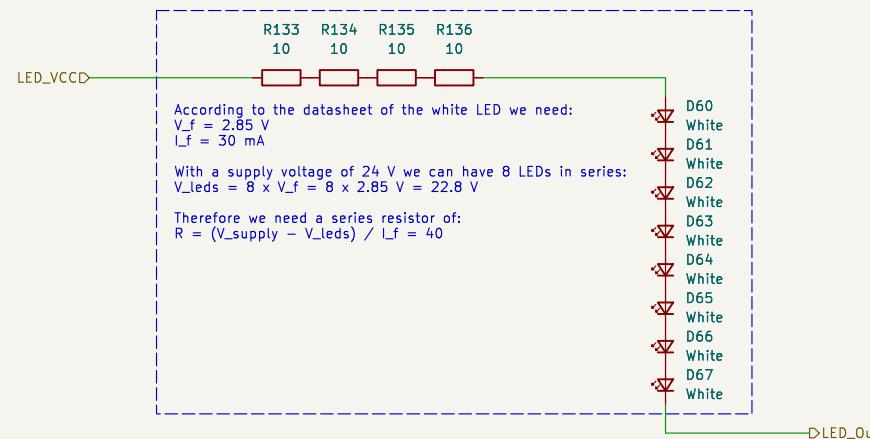
B

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Sheet: /LED\_Control/8xLED\_White7/  
File: 8xLED\_White.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 44/68

A

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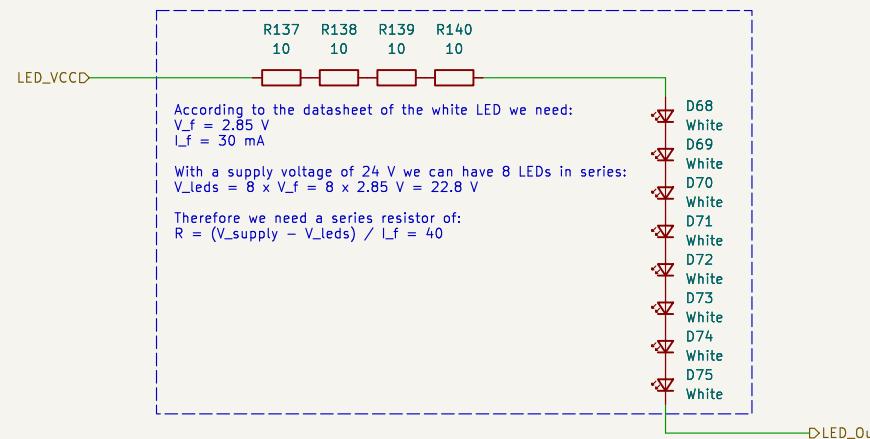
B

C

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Sheet: /LED\_Control/8xLED\_White8/  
File: 8xLED\_White.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 45/68

A

A

B

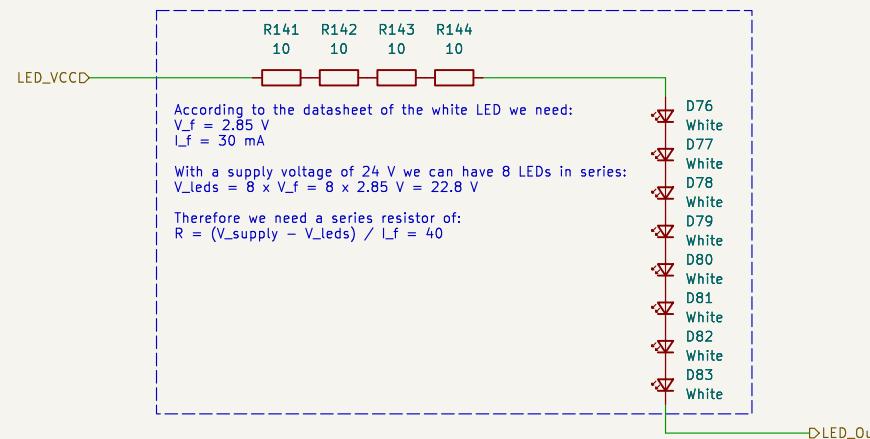
B

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Sheet: /LED\_Control/8xLED\_White9/  
File: 8xLED\_White.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 46/68

A

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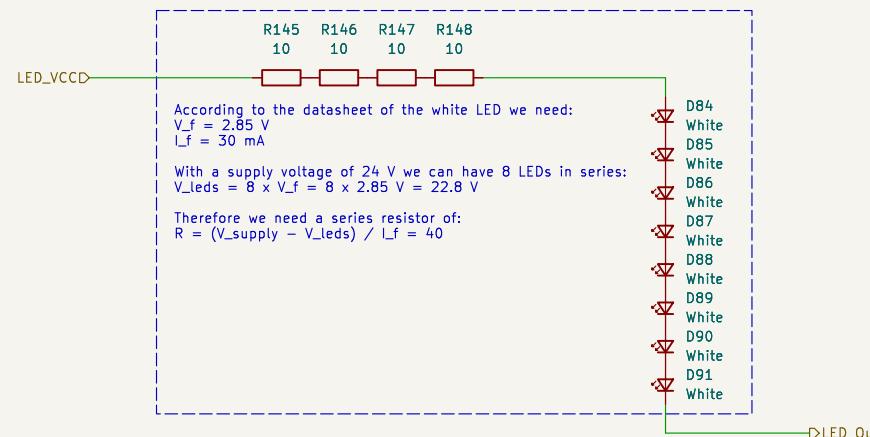
B

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Sheet: /LED\_Control/8xLED\_White10/  
File: 8xLED\_White.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 47/68

A

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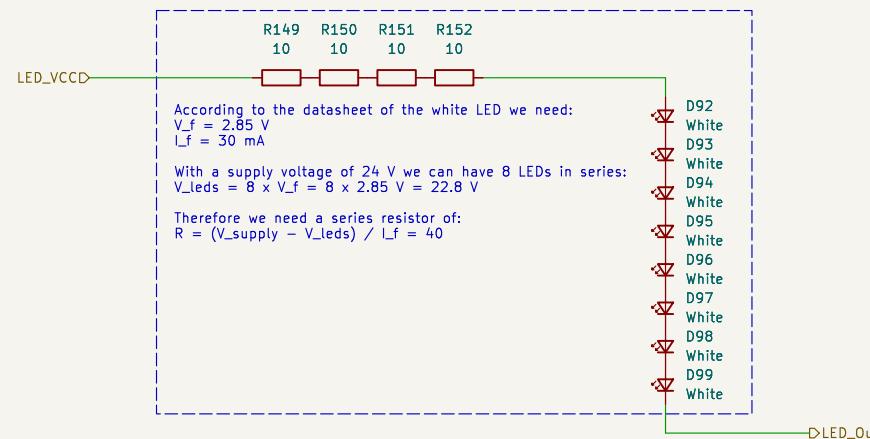
B

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Sheet: /LED\_Control/8xLED\_White11/  
File: 8xLED\_White.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 48/68

A

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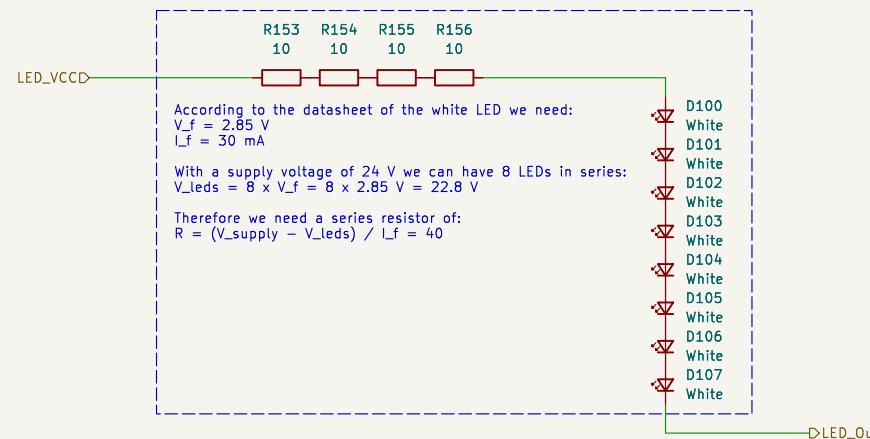
B

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Sheet: /LED\_Control/8xLED\_White12/  
File: 8xLED\_White.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 49/68

A

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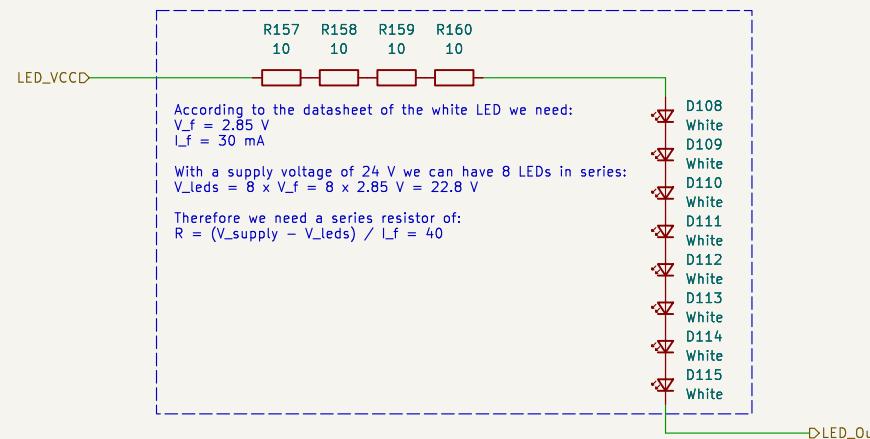
B

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Sheet: /LED\_Control/8xLED\_White13/  
File: 8xLED\_White.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 50/68

A

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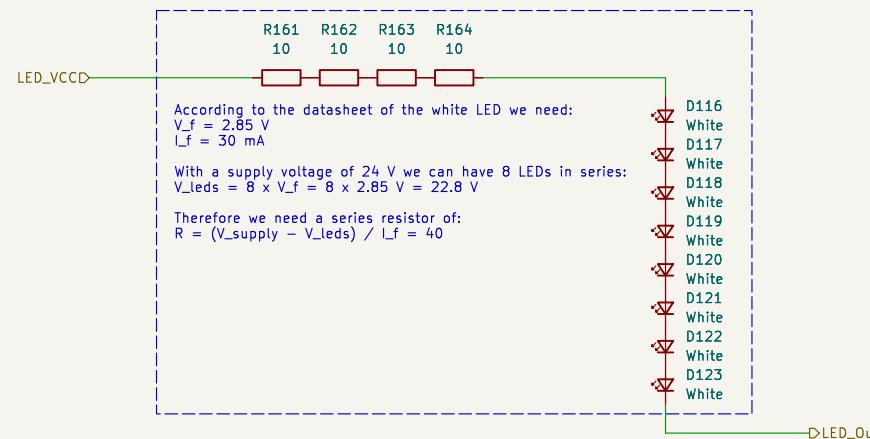
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File: 8xLED\_White.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 51/68

A

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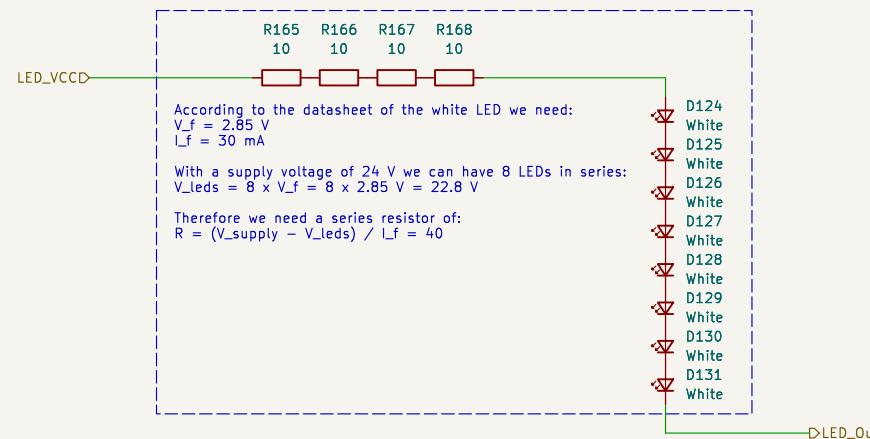
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File: 8xLED\_White.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 52/68

A

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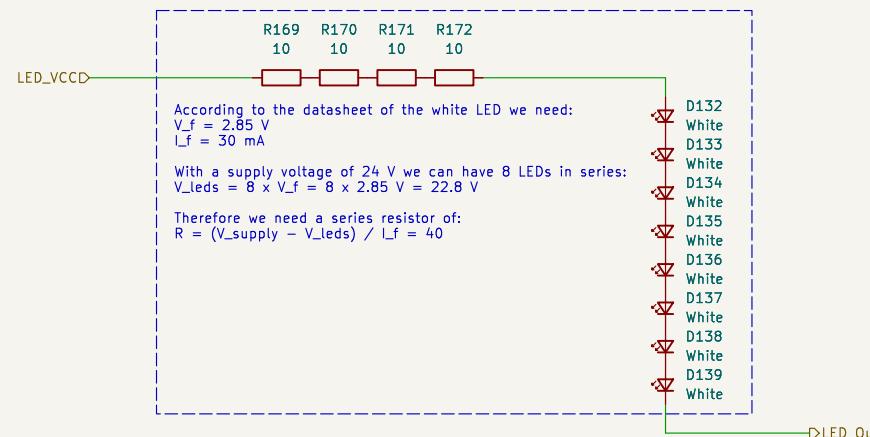
B

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Sheet: /LED\_Control/8xLED\_White16/  
File: 8xLED\_White.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 53/68

A

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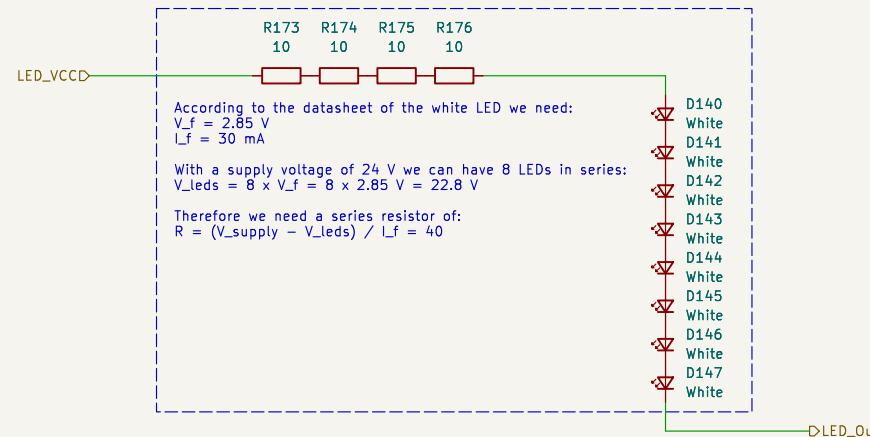
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Sheet: /LED\_Control/8xLED\_White17/  
File: 8xLED\_White.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 54/68

A

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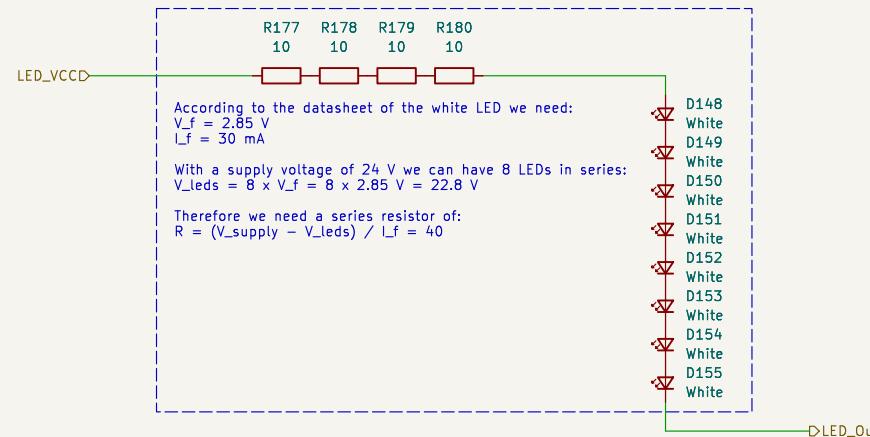
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Sheet: /LED\_Control/8xLED\_White18/  
File: 8xLED\_White.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 55/68

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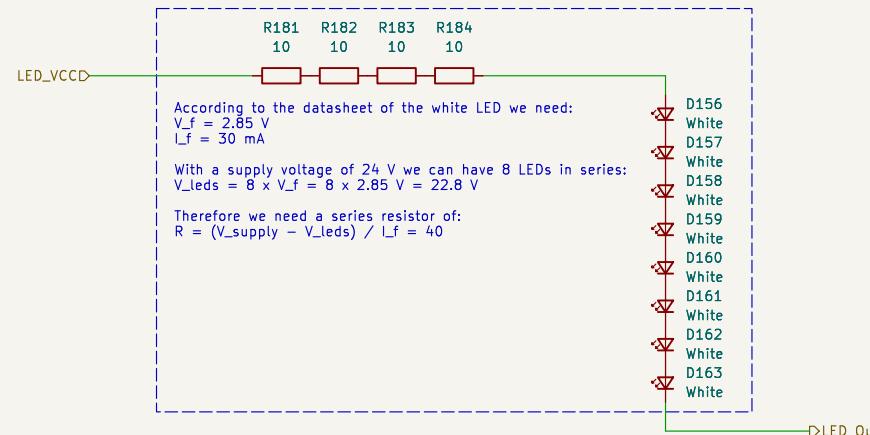
B

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Sheet: /LED\_Control/8xLED\_White19/  
File: 8xLED\_White.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 56/68

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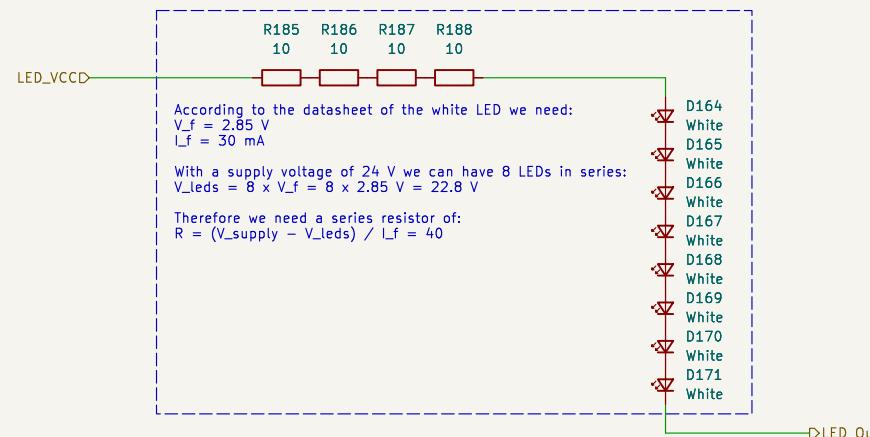
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Sheet: /LED\_Control/8xLED\_White20/  
File: 8xLED\_White.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 57/68

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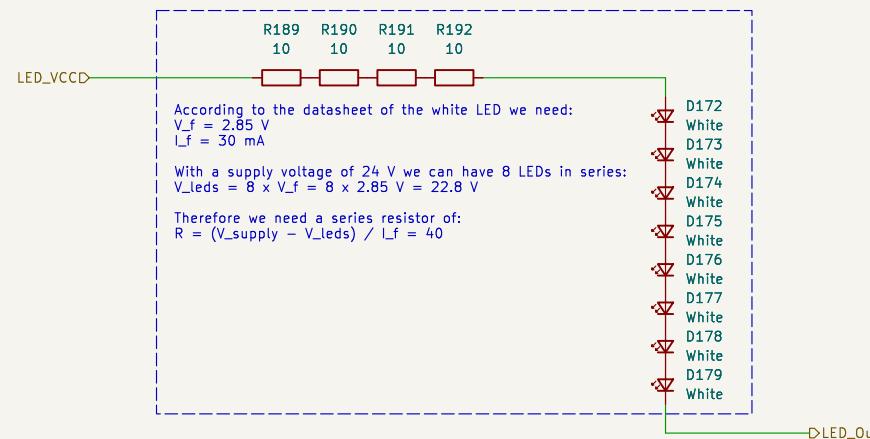
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File: 8xLED\_White.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 58/68

A

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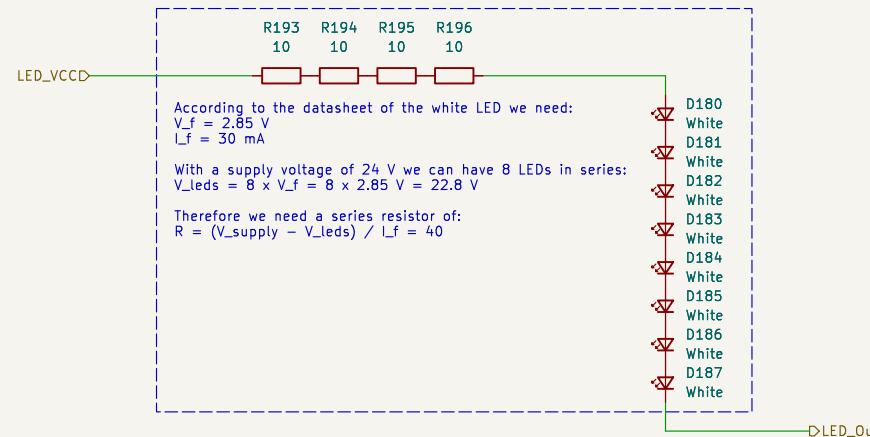
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Sheet: /LED\_Control/8xLED\_White22/  
File: 8xLED\_White.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 59/68

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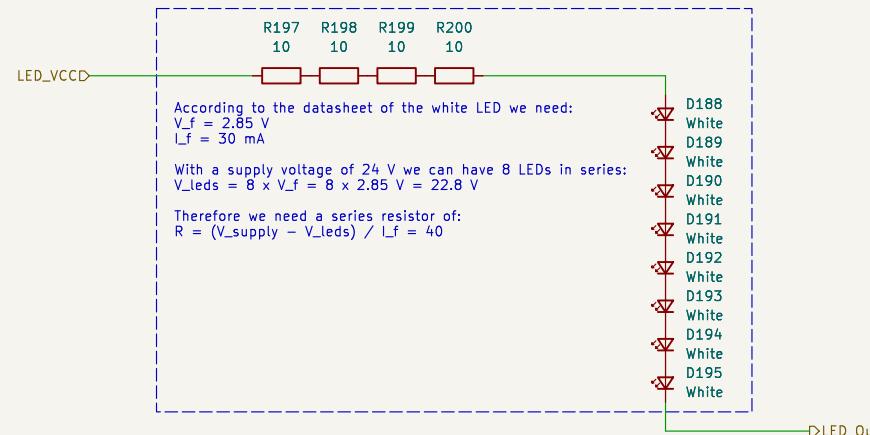
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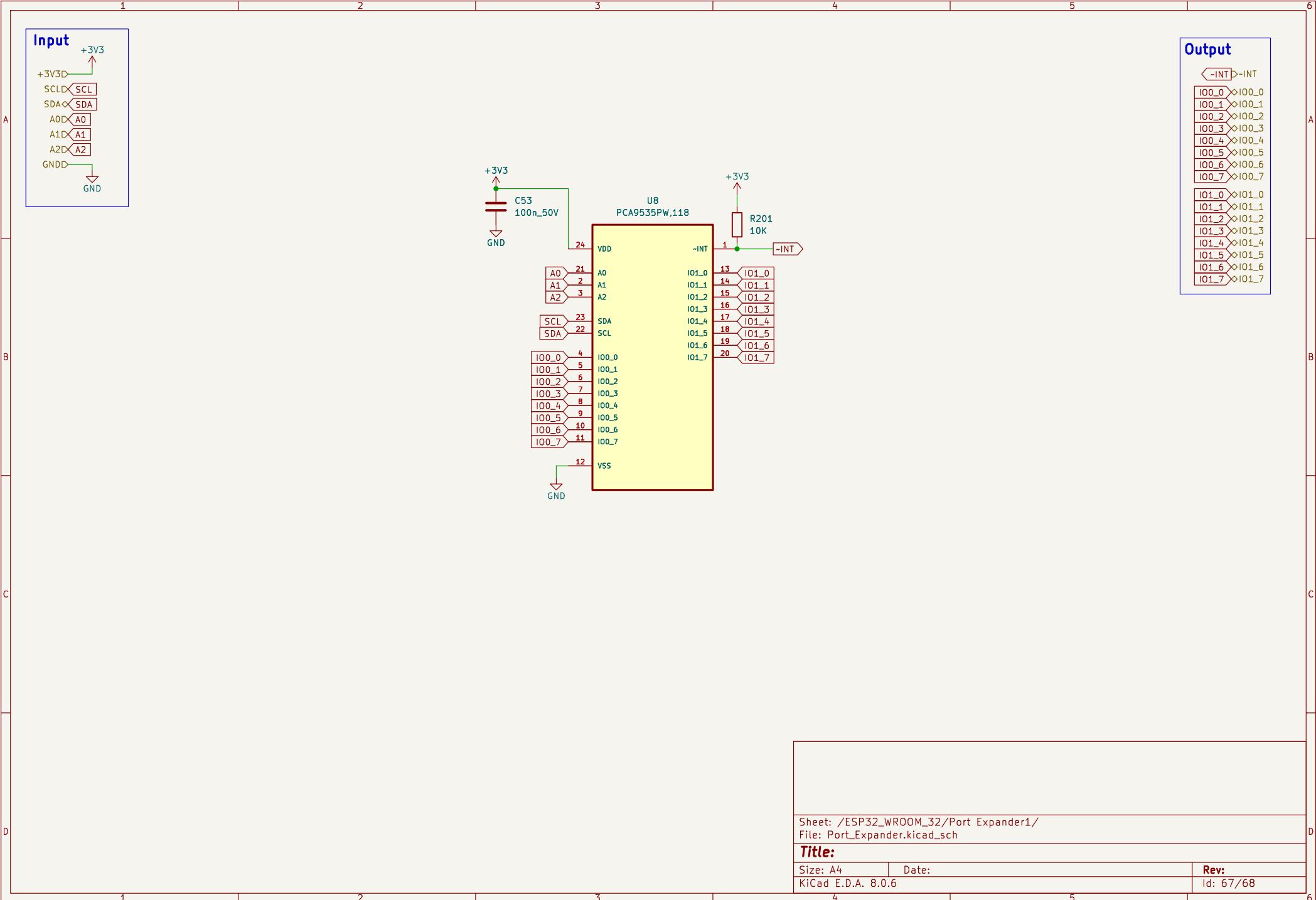


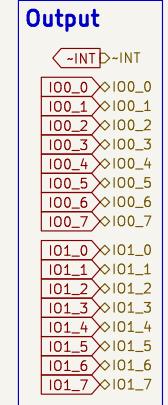
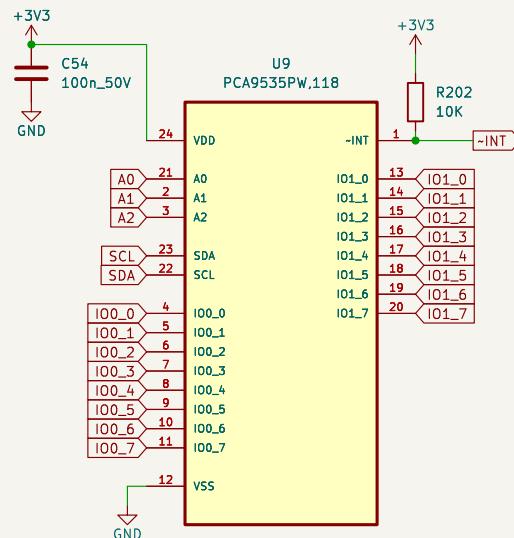
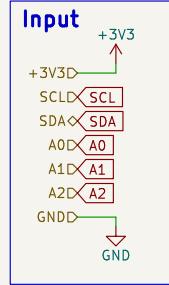
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File: 8xLED\_White.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 60/68



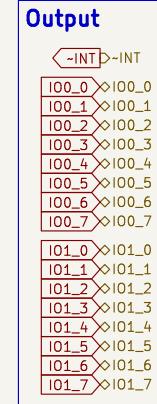
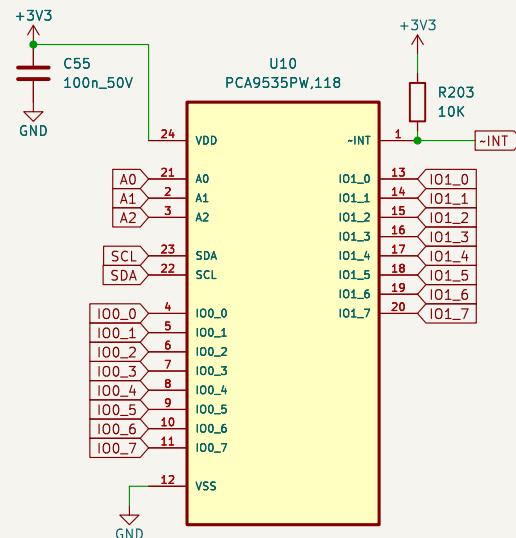
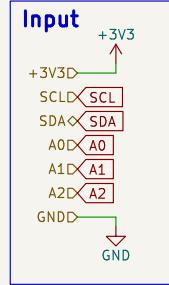


Sheet: /ESP32\_WROOM\_32/Port\_Expander2/  
File: Port\_Expander.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 68/68

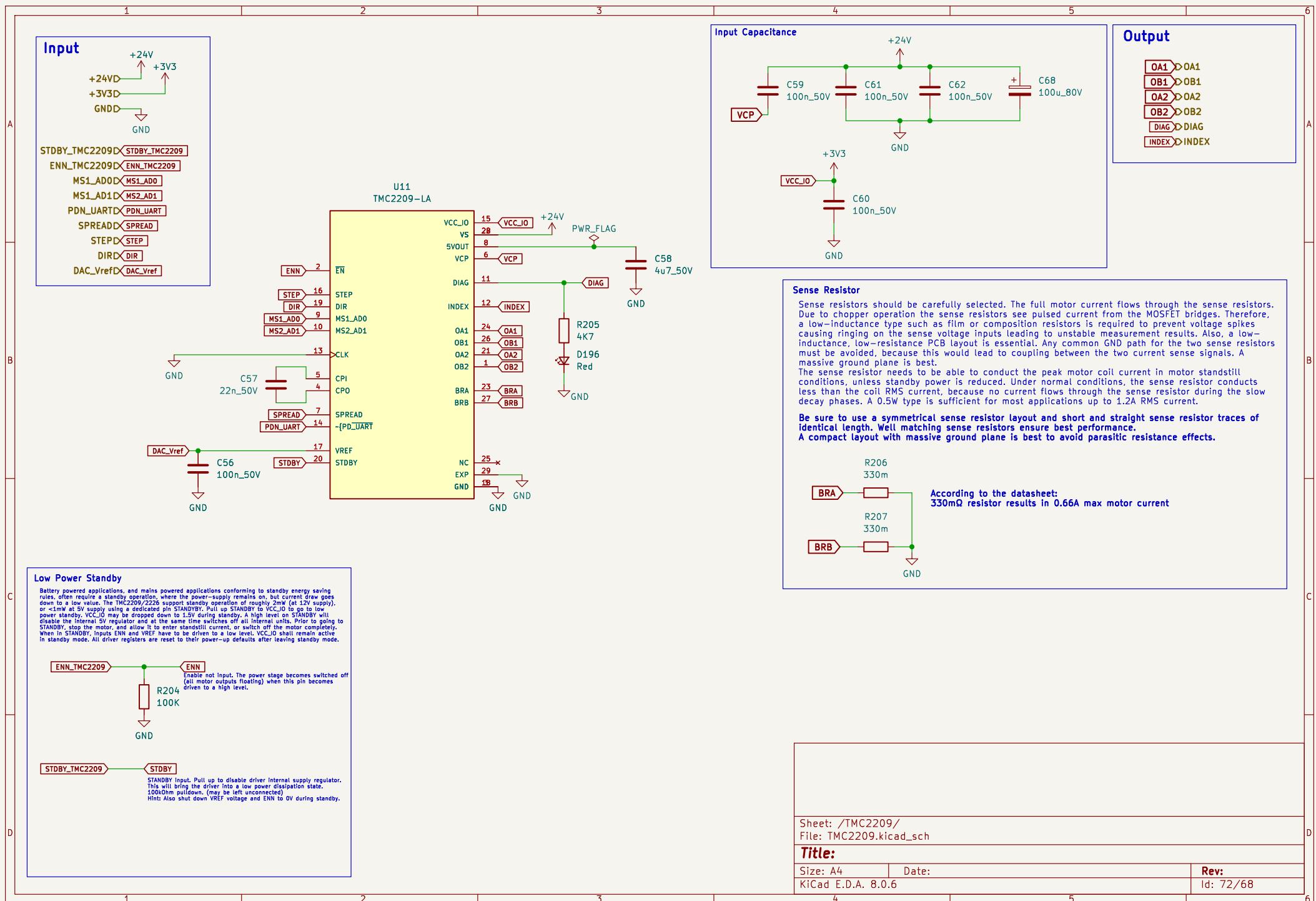


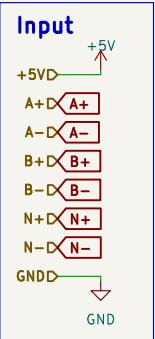
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File: Port\_Expander.kicad\_sch

**Title:**

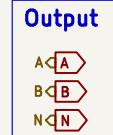
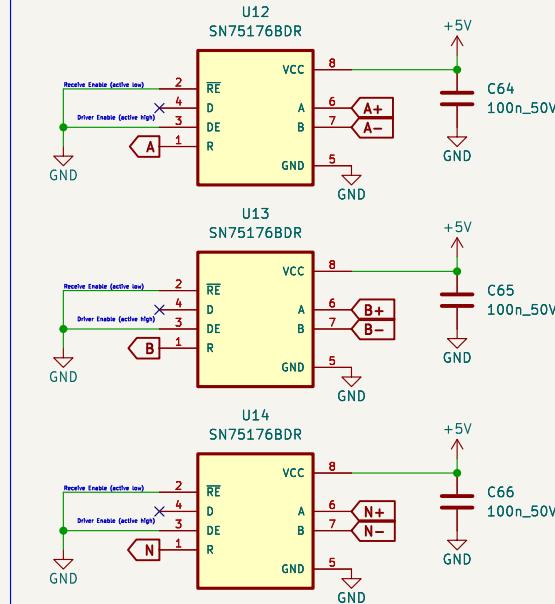
Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 69/68





### Differential Line Receiver



Sheet: /Differential\_Line\_Receiver/  
File: Differential\_Line\_Receiver.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 74/68

1 2 3 4 5 6

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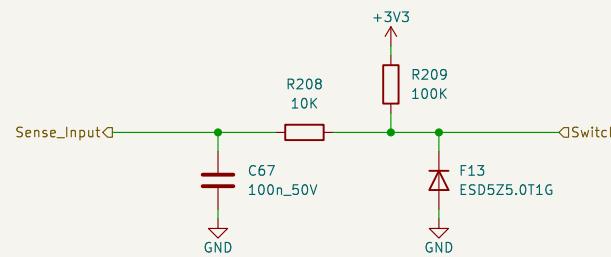
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Sheet: /Ext\_Switch\_Sensing\_Drawer\_1/  
File: Ext\_Switch\_Sensing.kicad\_sch

**Title:**

Size: A4 | Date:  
KiCad E.D.A. 8.0.6

**Rev:**  
Id: 75/68

1 2 3 4 5 6