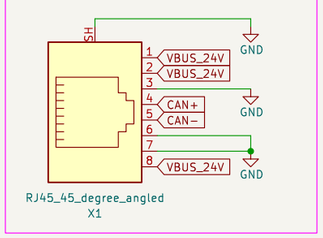
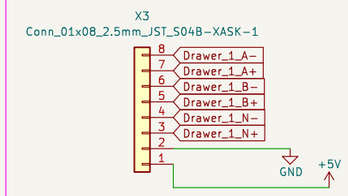
Input

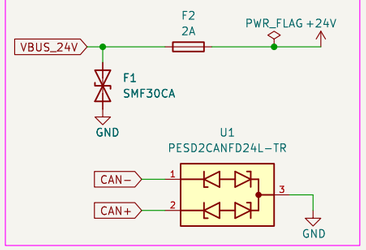
CAN and Power Input



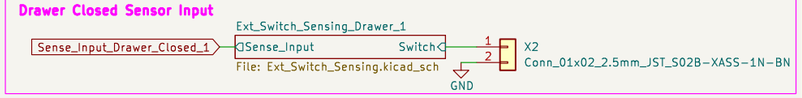
Drawer Encoder Sensor Input



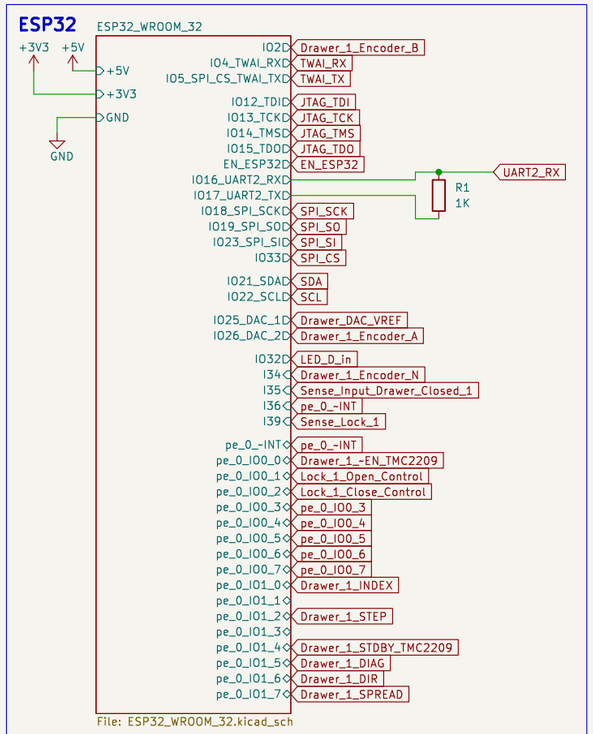
Input protection



Drawer Closed Sensor Input

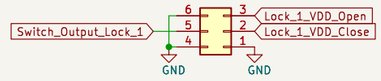


ESP32

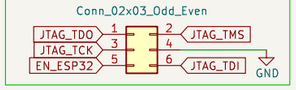


Output

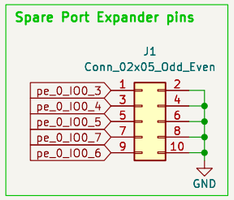
Locks



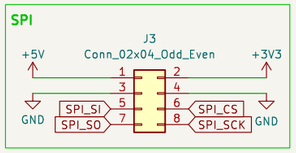
JTAG Debugging



Spare Port Expander pins

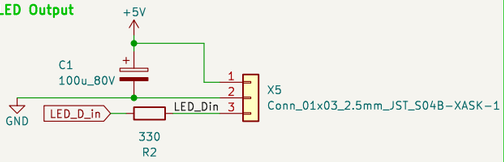


SPI

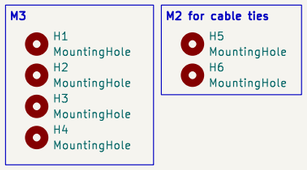


Electrical Drawer

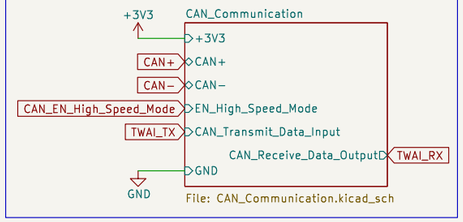
LED Output



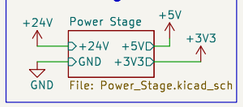
Mounting Holes



CAN Communication

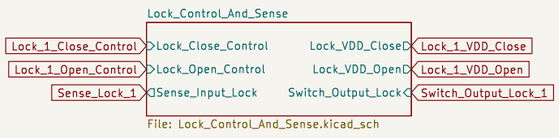


Power Stage

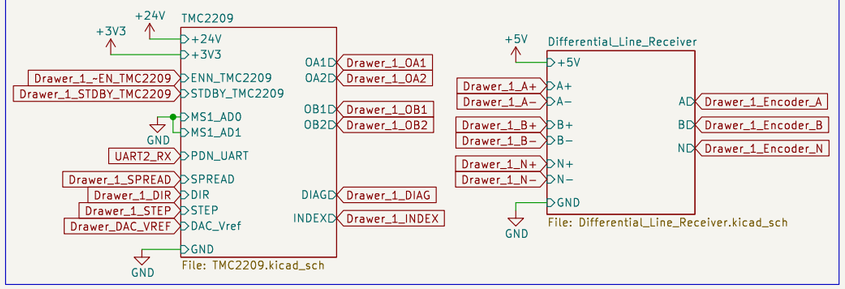


Attention:
To flash the ESP, the IO2 Pin of the ESP needs to be pulled down.
This can be done by pulling Drawer_1_B+ to GND.
(this should be fixed in the next version)

Lock Control and Sense



Electrical Drawer with Encoder



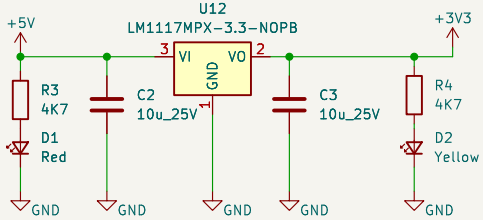
Sheet: /
File: Drawer_Controller_v4_hotfix.kicad_sch

Title:

Size: A3	Date:	**Rev:**
KiCad E.D.A. 8.0.6		Id: 1/12

Input

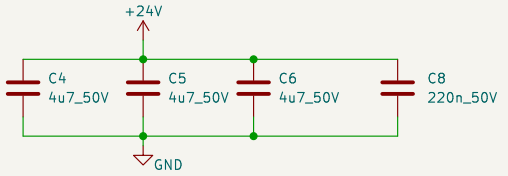
5V to 3.3V



24V to 5V

Input Capacitor

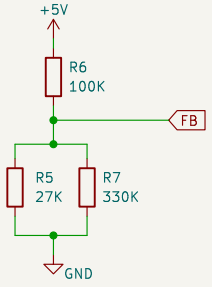
A minimum of 10 µF of ceramic capacitance is required on the input of the LMR33630.
This must be rated for at least the maximum input voltage that the application requires; preferably twice the maximum input voltage. This capacitance can be increased to help reduce input voltage ripple and maintain the input voltage during load transients. In addition, a small case size, 220-nF ceramic capacitor must be used at 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-µF, 50-V, X7R (or better like C0G) ceramic capacitor is chosen. The 220 nF must also be rated at 50 V with an X7R or C0G dielectric.
Please mind that the small capacitor should have a smaller footprint to have smaller ESL.
https://www.signalintegrityjournal.com/articles/1589-the-myth-of-three-capacitor-values



Reference Voltage

Ouput Voltage Set-Point:
R1 = R2 / (V_Out/1V) - 1)
R1 = 100k / (5V - 1V)
= 25k

Please mind:
R2 is recommended to be app. 100kΩ
For R1 = 24.9k is chosen as recommended in the datasheet.
27k||330k = 27k*330k / (27k+330k)
= 24,958



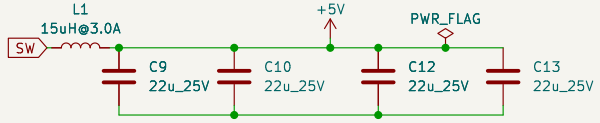
Output Filter

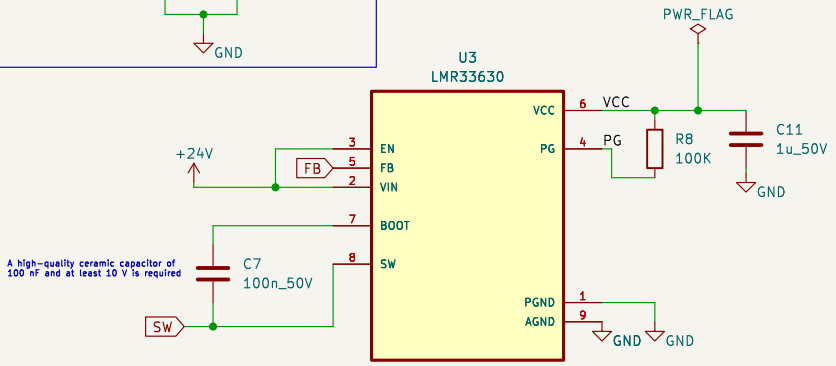
Inductor Selection
The parameters for selecting the inductor are the inductance and saturation current. The inductance is based on the desired peak-to-peak ripple current and is normally chosen to be in the range of 20% to 40% of the maximum output current. Experience shows that the best value for inductor 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 from the device, the maximum device current should be used. Equation 4 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 = ((VIN - VOut) x (VOut / VIn)) / (fSW x K x IOutMax)
= (24V - 5V) x (5V / 24V) / (400kHz x 0.3 x 2.3A)
= 14.34µH
Therefore we take the next available standard inductor value of 15uH.

For this example, a ΔVOUT ≤ 250 mV for an output current step of ΔIOUT = 2 A is required. Equation 6 gives a minimum value of 52 µF and a maximum ESR of 0.11 Ω.
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 V for output voltages of 3.3 V or less and a capacitor of 16 V or more for output voltages of 5 V and above.

For the capacitor we use 4 x 25V 22uF X5R ±10% 1206 Multilayer Ceramic Capacitors MLCC (CL31A226KAHNNNE).
If you check the specifactions under
https://product.samsungsem.com/micc/CL31A226KAHNNNN.do

You can find, that the DC Bias at 5V DC is -37.96% of the original capacity, so
Co = 4 x 22uF x 0.62 = 54.56µF
To find out the RESR 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 at least what they did 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/micc/info?part_no=C3216X5R0J476M160AC
Following this procedure, the ESR value for ONE CL31A226KAHNNNE is something like:
RESR,1xC = 3.82mOhm = 0.00382 Ohm





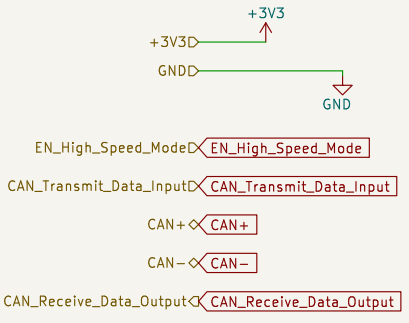
Output

Sheet: /Power Stage/
File: Power_Stage.kicad_sch

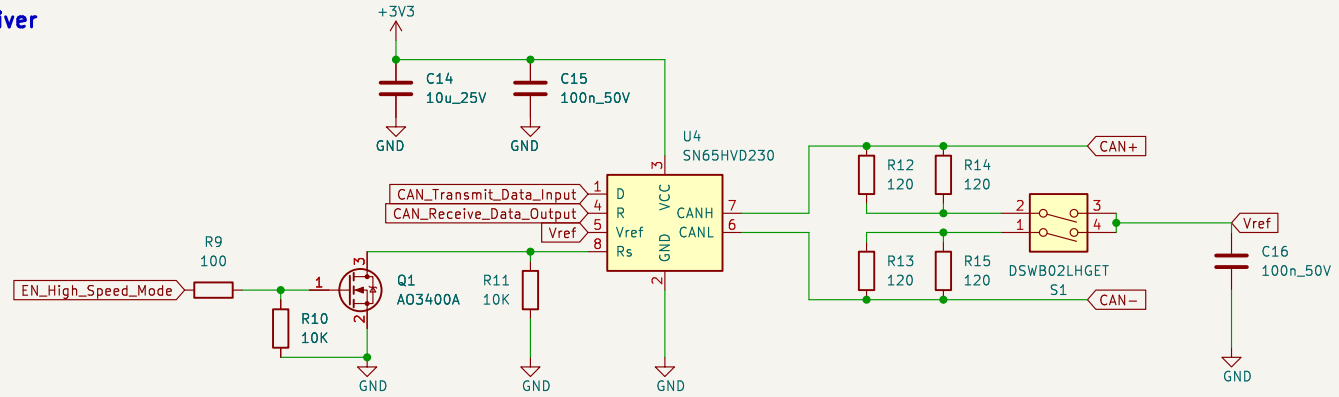
Title:

Size: A4	Date:	**Rev:**
KiCad E.D.A. 8.0.6		Id: 2/12

Input/Output

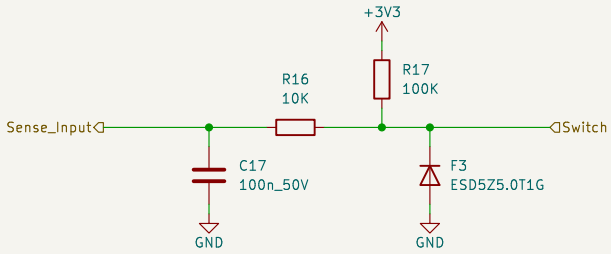


CAN Transceiver



The RS pin (pin 8) on the SN65HVD230 and SN65HVD231 provides three different modes of operation: high speed mode, slope control mode, and low−power mode. The high speed mode of operation is selected by connecting the RS pin to ground, allowing the transmitter output transistors to switch on and off as fast as possible with no limitation on the rise and fall slopes. The rise and fall slopes can also be adjusted by connecting a resistor in series between the RS pin and ground. The slope will be proportional to the pin's output current. With a resistor value of 10 kΩ the device will have a slew rate of ~15 V/µs, and with a resistor value of 100 kΩ the device will have a slew rate of ~2 V/µs.

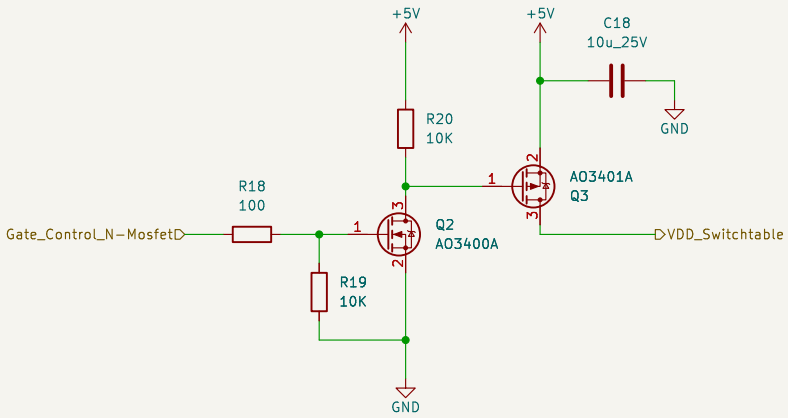
Sheet: /CAN_Communication/		
File: CAN_Communication.kicad_sch		
Title:		
Size: A4	Date:	**Rev:**
KiCad E.D.A. 8.0.6		Id: 3/12



Sheet: /Lock_Control_And_Sense/Ext_Switch_Sensing/
File: Ext_Switch_Sensing.kicad_sch

Title:

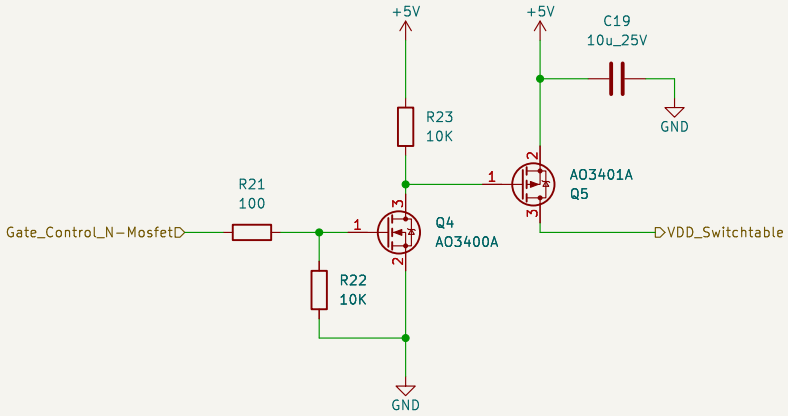
Size: A4	Date:	**Rev:**
KiCad E.D.A. 8.0.6		Id: 4/12



Sheet: /Lock_Control_And_Sense/VDD_Switch_Lock_Close/
File: VDD_Switch.kicad_sch

Title:

Size: A4	Date:	**Rev:**
KiCad E.D.A. 8.0.6		Id: 5/12

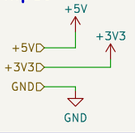


Sheet: /Lock_Control_And_Sense/VDD_Switch_Lock_Open/
File: VDD_Switch.kicad_sch

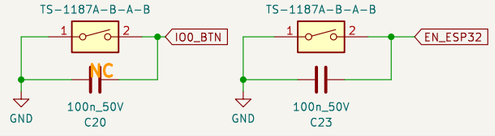
Title:

Size: A4	Date:	**Rev:**
KiCad E.D.A. 8.0.6		Id: 6/12

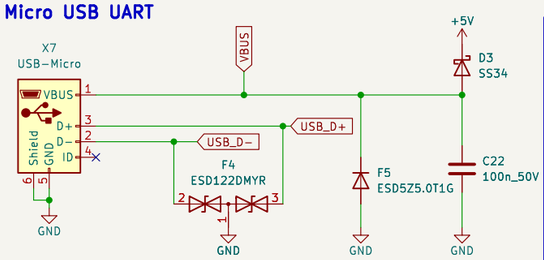
Input

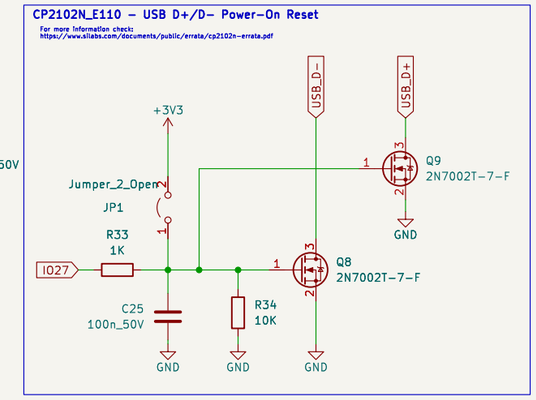


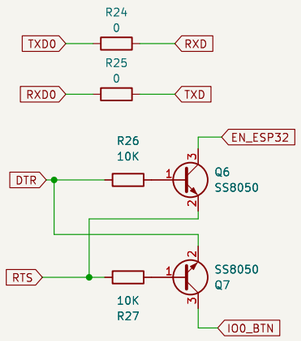
Switches

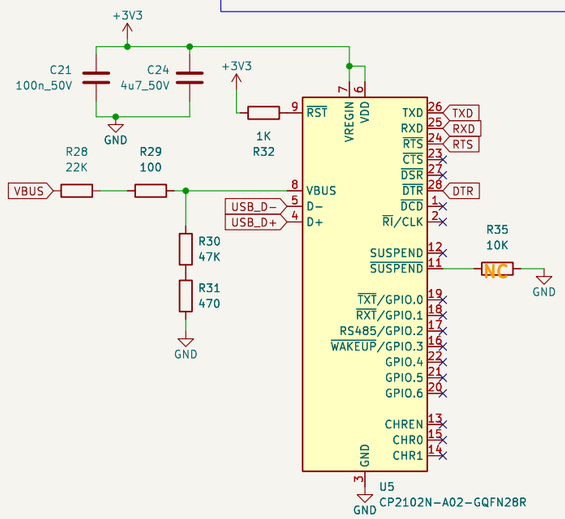


Micro USB UART

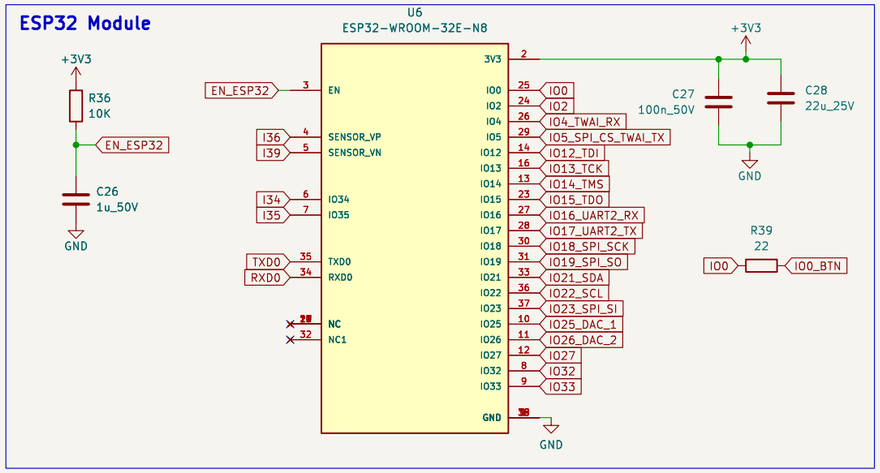








ESP32 Module



Port Expander

I2C Pullup Resistor

Application Report:
I2C Bus Pullup
Resistor Calculation

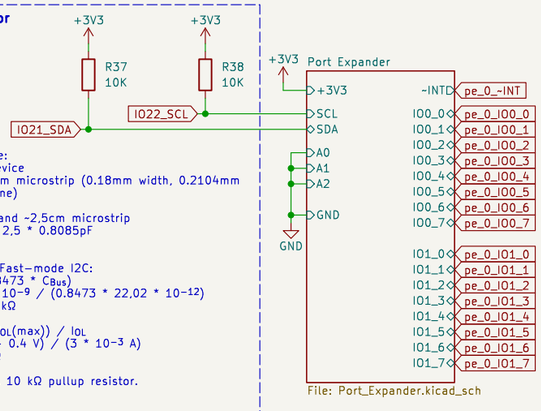
I2C Bus Capacitance:
– typ. ~10pF per device
– ~0.8085 pF per cm microstrip (0.18mm width, 0.2104mm above reference plane)

We have 2 devices and ~2.5cm microstrip
C_{Bus} = 2 * 10pF + 2,5 * 0.8085pF
= 22.02 pF

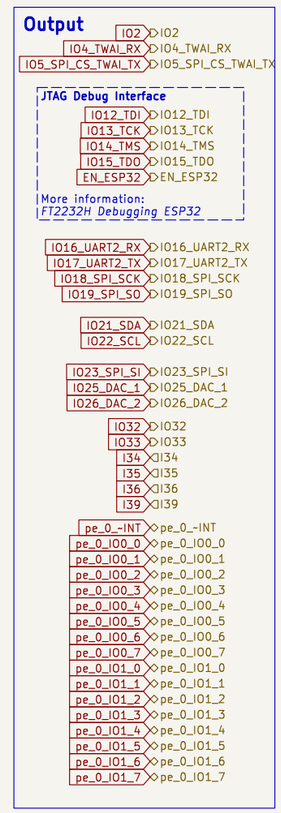
Pullup Resistor for Fast-mode I2C:
$R_P(max) = t_r / (0.8473 * C_{Bus})$
= 300 * 10-9 / (0.8473 * 22.02 * 10-12)
= 16.08 kΩ

$R_P(min) = (V_{CC} - V_{OL}(max)) / I_{OL}$
= (5 V – 0.4 V) / (3 * 10-3 A)
= 1.5 kΩ

So we can take e.g. 10 kΩ pullup resistor.

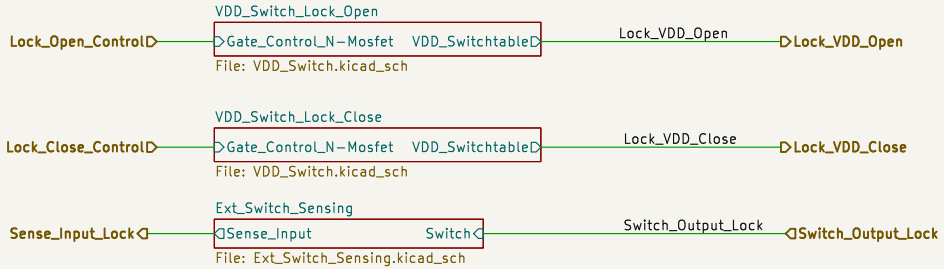


Output



Datasheets & References:
https://www.espressif.com/sites/default/files/documentation/esp32-wroom-32e_esp32-wroom-32ue_datasheet_en.pdf
https://dl.espressif.com/dl/schematics/esp32_devkitc_v4-sch.pdf
https://www.youtube.com/watch?v=S_pOYV-JlfU&t=4185s

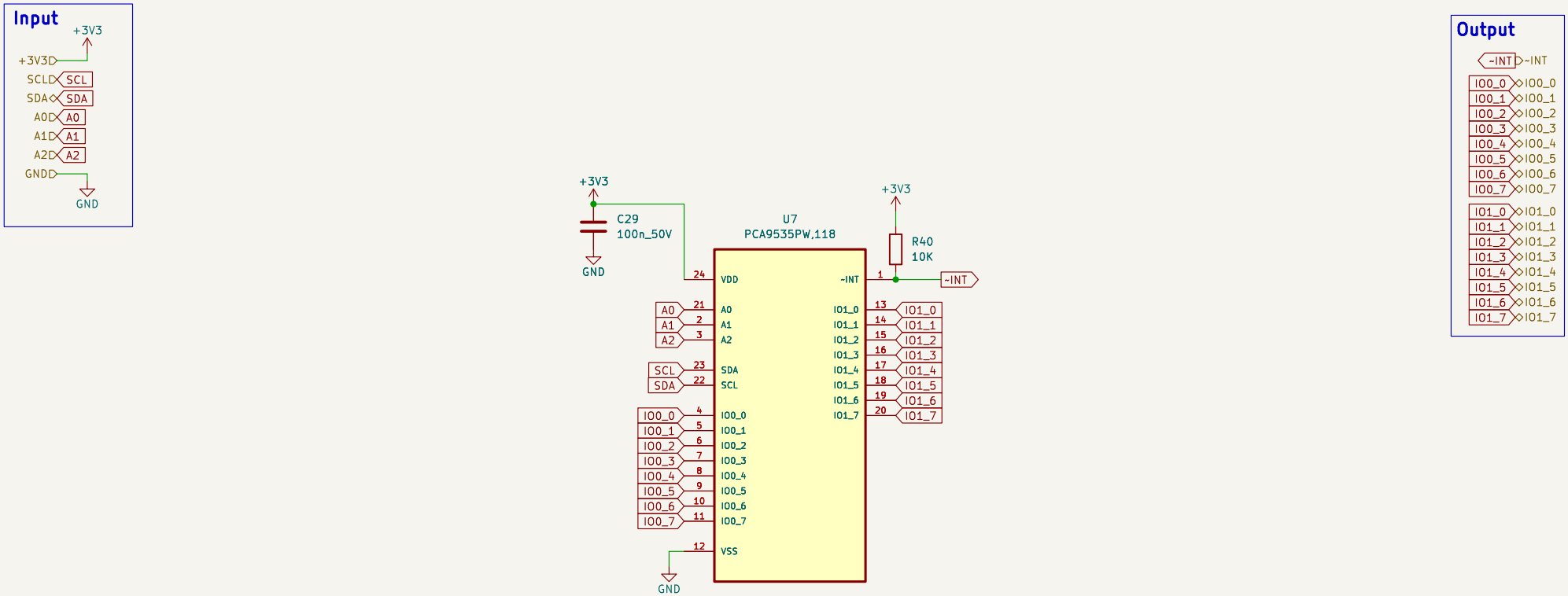
Sheet: /ESP32_WROOM_32/		
File: ESP32_WROOM_32.kicad_sch		
Title:		
Size: A3	Date:	**Rev:**
KiCad E.D.A. 8.0.6		Id: 7/12



Sheet: /Lock_Control_And_Sense/
File: Lock_Control_And_Sense.kicad_sch

Title:

Size: A4	Date:	**Rev:**
KiCad E.D.A. 8.0.6		Id: 15/12



Sheet: /ESP32_WROOM_32/Port Expander/
File: Port_Expander.kicad_sch

Title:

Size: A4	Date:	**Rev:**
KiCad E.D.A. 8.0.6		Id: 69/12

Input

+24V
+3V3
GND

STDBY_TMC2209
ENN_TMC2209
MS1_AD0
MS1_AD1
PDN_UART
SPREAD
STEP
DIR
DAC_Vref

Input Capacitance

+24V
C33 100n_50V
C35 100n_50V
C36 100n_50V
C37 100u_80V
VCP
GND
+3V3
VCC_IO
C34 100n_50V
GND

Output

OA1
OB1
OA2
OB2
DIAG
INDEX

U8 TMC2209-LA

Pin	Name	Net
15	VCC_IO	VCC_IO
28	VS	+24V
8	5VOUT	PWR_FLAG
6	VCP	VCP
11	DIAG	DIAG
12	INDEX	INDEX
24	OA1	OA1
26	OB1	OB1
21	OA2	OA2
1	OB2	OB2
23	BRA	BRA
27	BRB	BRB
25	NC	
29	EXP	GND
13	GND	GND
2	EN	ENN
16	STEP	STEP
19	DIR	DIR
9	MS1_AD0	MS1_AD0
10	MS2_AD1	MS2_AD1
13	CLK	GND
5	CPI	C31 22n_50V
4	CPO	
7	SPREAD	SPREAD
14	~{PD_UART}	PDN_UART
17	VREF	DAC_Vref
20	STDBY	STDBY

C32 4u7_50V
R42 4K7
D4 Red
C30 100n_50V

Sense Resistor

Sense resistors should be carefully selected. The full motor current flows through the sense resistors. Due to chopper operation the sense resistors see pulsed current from the MOSFET bridges. Therefore, a low-inductance type such as film or composition resistors is required to prevent voltage spikes causing ringing on the sense voltage inputs leading to unstable measurement results. Also, a low-inductance, low-resistance PCB layout is essential. Any common GND path for the two sense resistors must be avoided, because this would lead to coupling between the two current sense signals. A massive ground plane is best.
The sense resistor needs to be able to conduct the peak motor coil current in motor standstill conditions, unless standby power is reduced. Under normal conditions, the sense resistor conducts less than the coil RMS current, because no current flows through the sense resistor during the slow decay phases. A 0.5W type is sufficient for most applications up to 1.2A RMS current.

Be sure to use a symmetrical sense resistor layout and short and straight sense resistor traces of identical length. Well matching sense resistors ensure best performance.
A compact layout with massive ground plane is best to avoid parasitic resistance effects.

R43 330m
BRA
R44 330m
BRB
GND

According to the datasheet:
330mΩ resistor results in 0.66A max motor current

Low Power Standby

Battery powered applications, and mains powered applications conforming to standby energy saving rules, often require a standby operation, where the power-supply remains on, but current draw goes down to a low value. The TMC2209/2226 support standby operation of roughly 2mW (at 12V supply). or <1mW at 5V supply using a dedicated pin STANDYBY. Pull up STANDBY to VCC_IO to go to low power standby. VCC_IO may be dropped down to 1.5V during standby. A high level on STANDBY will disable the internal 5V regulator and at the same time switches off all internal units. Prior to going to STANDBY, stop the motor, and allow it to enter standstill current, or switch off the motor completely. When in STANDBY, inputs ENN and VREF have to be driven to a low level. VCC_IO shall remain active in standby mode. All driver registers are reset to their power-up defaults after leaving standby mode.

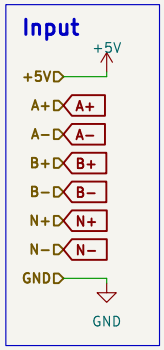
ENN_TMC2209 — ENN
Enable not input. The power stage becomes switched off (all motor outputs floating) when this pin becomes driven to a high level.
R41 100K
GND

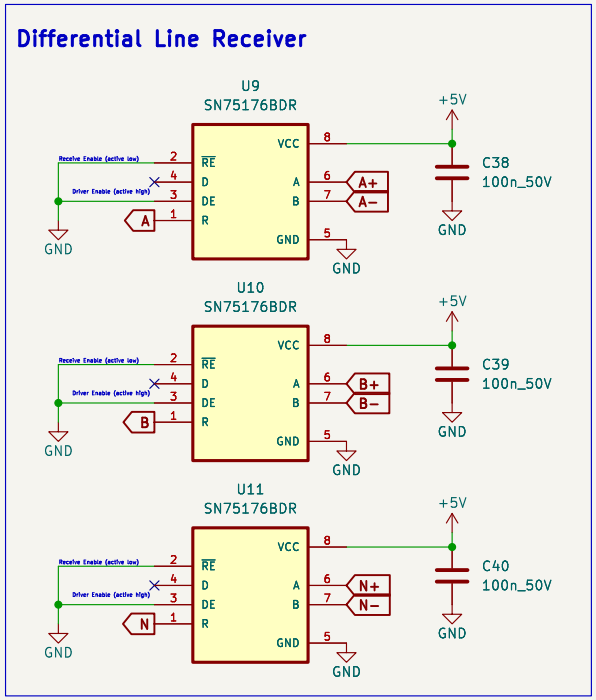
STDBY_TMC2209 — STDBY
STANDBY input. Pull up to disable driver internal supply regulator. This will bring the driver into a low power dissipation state. 100kOhm pulldown. (may be left unconnected)
Hint: Also shut down VREF voltage and ENN to 0V during standby.

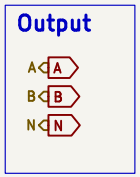
Sheet: /TMC2209/
File: TMC2209.kicad_sch

Title:

Size: A4	Date:	**Rev:**
KiCad E.D.A. 8.0.6		Id: 72/12



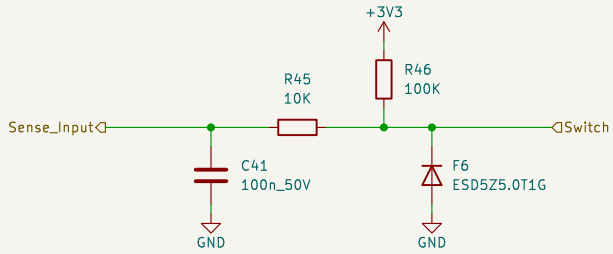




Sheet: /Differential_Line_Receiver/
File: Differential_Line_Receiver.kicad_sch

Title:

Size: A4	Date:	**Rev:**
KiCad E.D.A. 8.0.6		Id: 74/12



Sheet: /Ext_Switch_Sensing_Drawer_1/
File: Ext_Switch_Sensing.kicad_sch

Title:

Size: A4	Date:	**Rev:**
KiCad E.D.A. 8.0.6		Id: 75/12