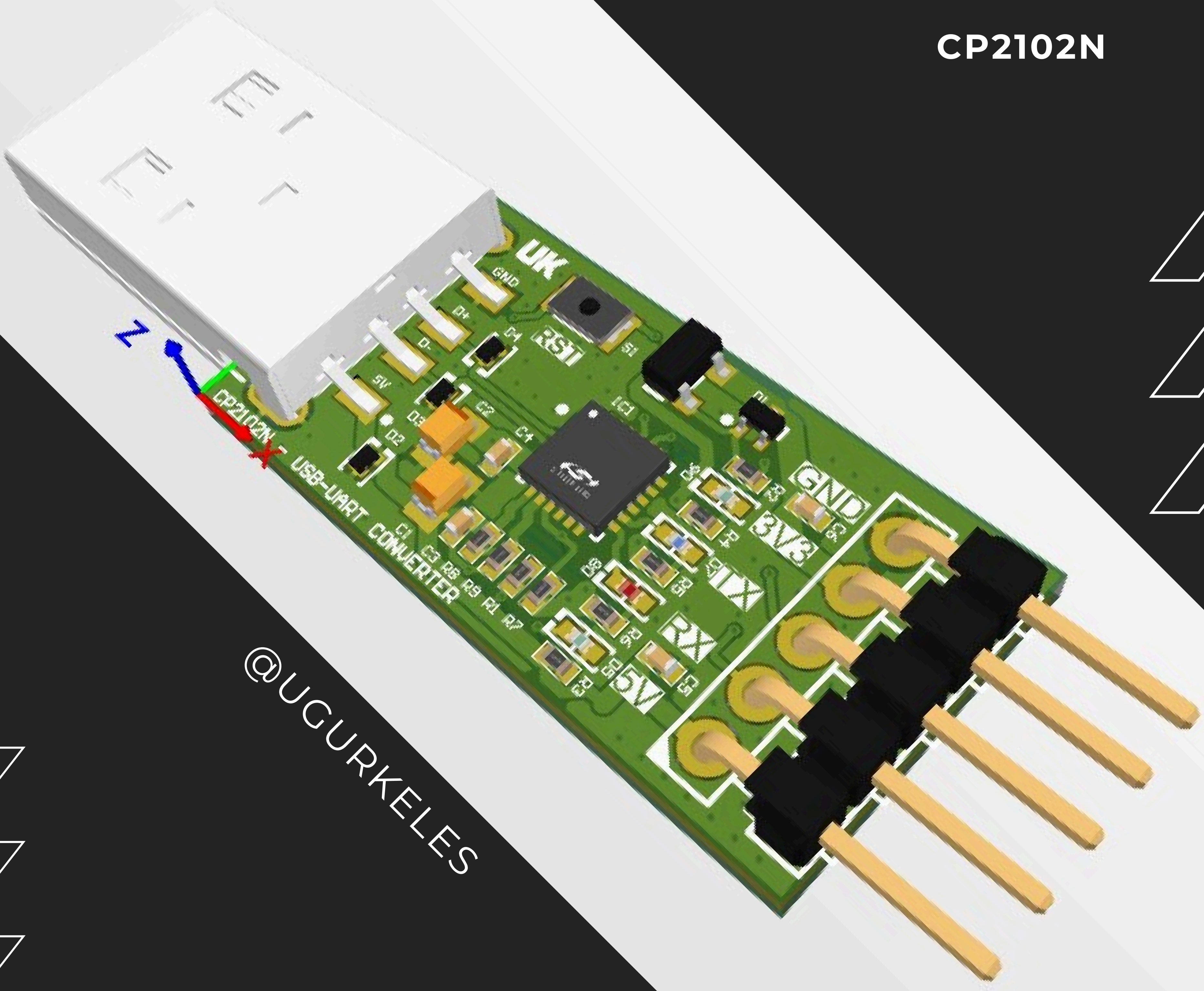
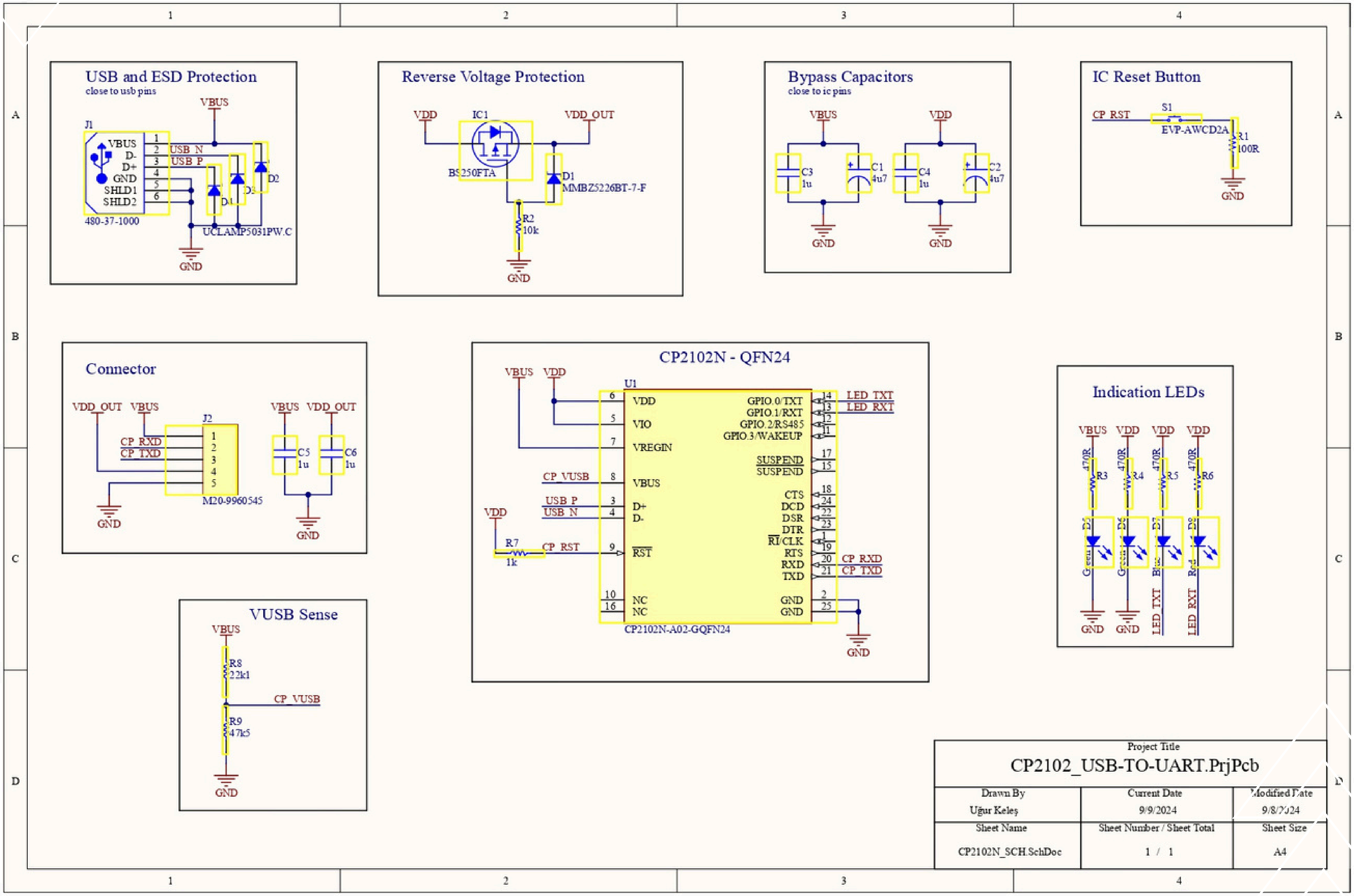
# USB UART CONVERTER

**CP2102N**




@UGURKELES

# 3D VIEW


USB and ESD Protection
close to usb pins
Reverse Voltage Protection
Bypass Capacitors
close to ic pins
IC Reset Button
Connector
CP2102N - QFN24
Indication LEDs
VUSB Sense
480-37-1000
UCLAMP5031PW.C
BS250FTA
MMBZ5226BT-7-F
EVP-AWCD2A
M20-9960545
CP2102N-A02-GQFN24
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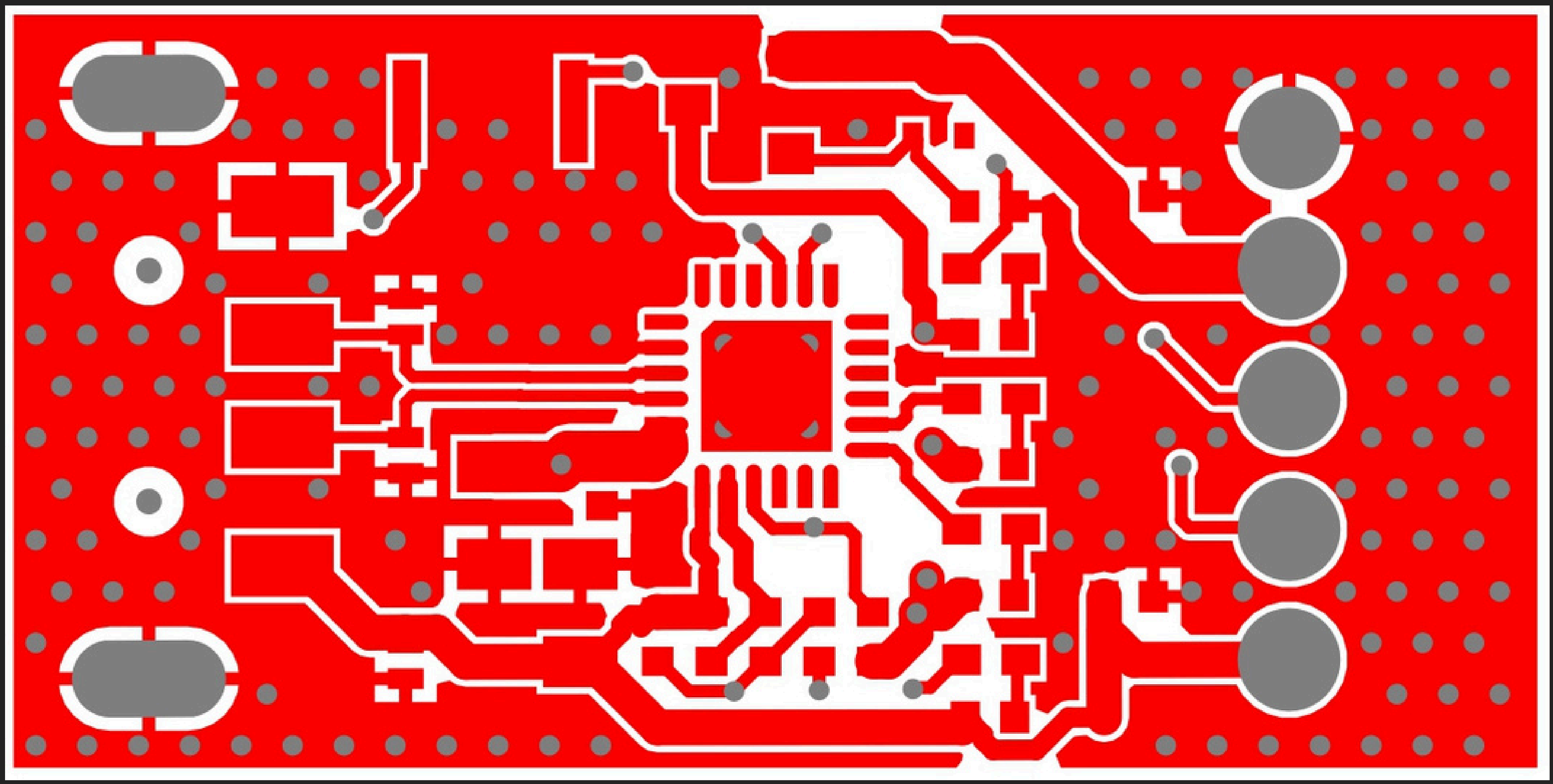
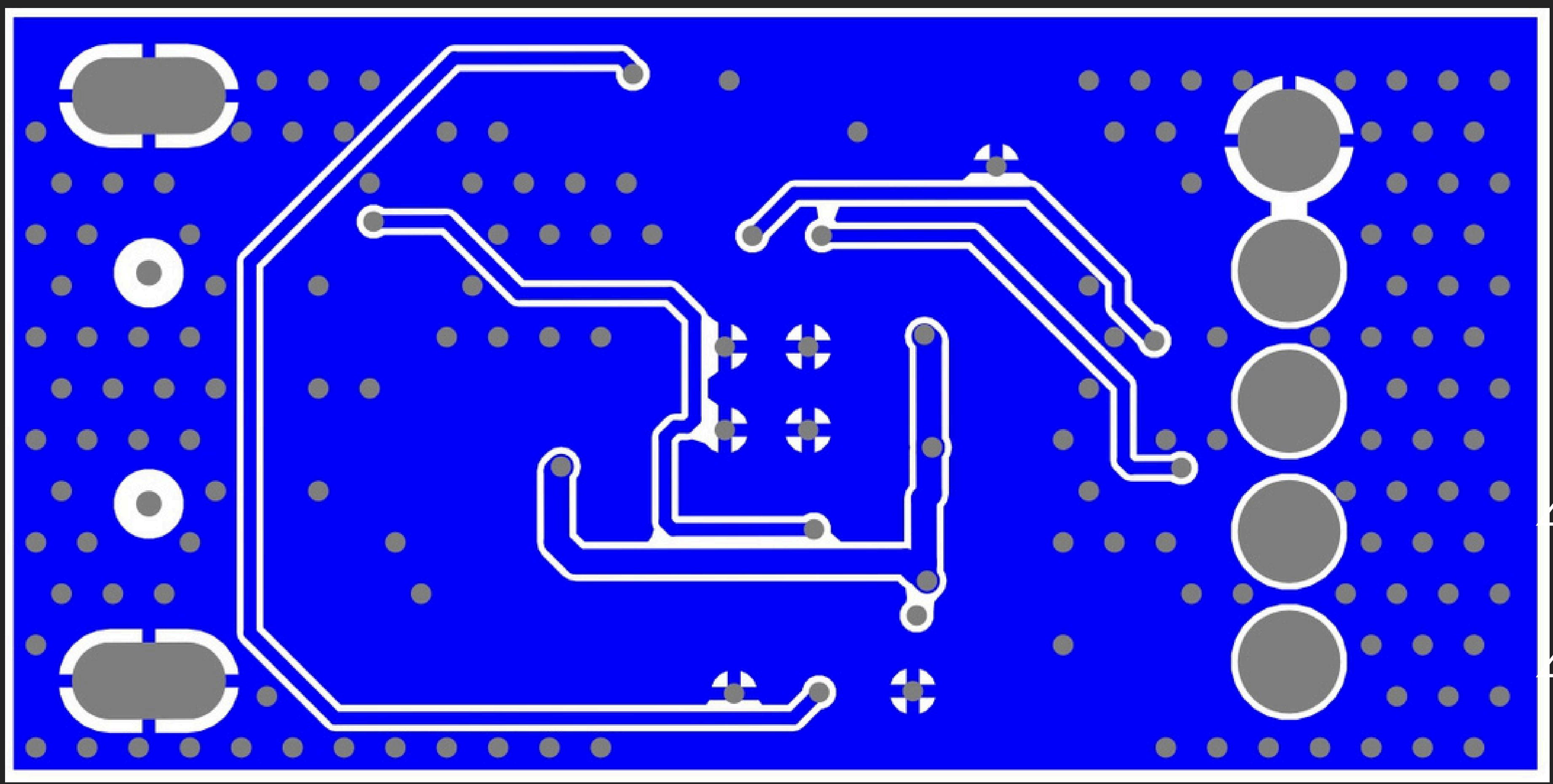
# SCHEMATICS





# TOP AND BOTTOM LAYERS

# What is USB?

USB (Universal Serial Bus) provides a reliable and standardized method for data transfer between a host (e.g., computer) and various devices (e.g., printers, external drives, keyboards). The USB system consists of a host, hubs, ports, and connected devices, with the host managing communication by assigning addresses to devices and utilizing endpoints for data exchange. Communication uses data pipes, logical channels that link the host to device endpoints, allowing data transfer types such as control (for commands), interrupt (for small data like mice inputs), bulk (for large data like printing), and isochronous (for real-time data like audio).

## USB Standards

- USB 1.0 and 1.1
- USB 2.0
- USB 3.0 and 3.1
- USB 3.2
- USB 4.0

## Key Features

- Plug and Play
- Hot Swappable
- Power Supply

## USB Connectors

- USB A
- USB B
- USB C
- USB Mini (A,B)
- USB Micro (A,B)

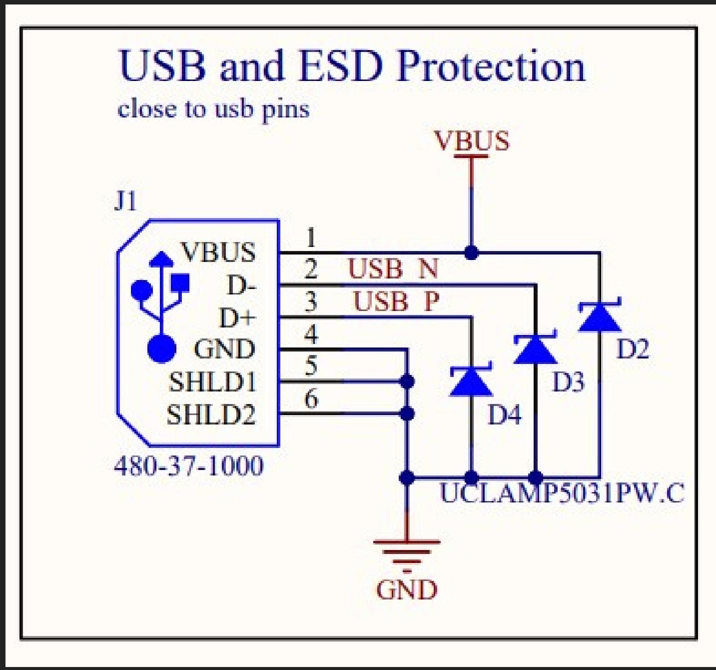
# USB Operation

USB employs differential signaling with twisted pairs (D+ and D- for USB 1 and 2, additional lines for USB 3 and above) to minimize interference and maintain signal integrity. Data is encoded using Non-Return to Zero Inverted (NRZI) encoding, which helps reduce errors during transfer. When a new device connects, the host assigns an address through a process called enumeration, allowing the device to communicate using defined USB data packets—token, data, handshake, and start of frame. These packets facilitate transactions that include synchronization fields and error checking (like CRC), making USB a robust solution for various data transfer needs. The USB protocol has evolved from USB 1 to USB 4, significantly increasing data rates and enhancing connectivity while maintaining core principles of operation.

# USB AND ESD PROTECTION - 1

# USB SCHEMATICS AND LAYOUT

- Place decoupling capacitors to filter out noise.
- Data lines should be routed as a differential pair with a controlled impedance (90ohm).
- Keep the traces as short as possible to minimize signal degradation.
- Use a continuous ground plane.
- Add ESD protection to the lines.
- Follow USB-IF standards.




## ESD Protection

ESD Protection safeguards electronic components from electrostatic discharge (ESD), which can cause damage or malfunction.

## Methods

- **TVS Diodes:** Fast-acting devices that clamp voltage spikes and absorb ESD energy, available in unidirectional (for positive voltages) and bidirectional (for both positive and negative voltages) forms. They are widely used due to their quick response time and robustness.
- **Clamping Diodes:** Commonly integrated in ICs, clamping diodes redirect ESD currents to VDD or GND, protecting sensitive inputs. They are often paired with capacitors to absorb ESD energy effectively.

## Layout Considerations

- Minimize trace lengths to reduce inductance and improve response time.
- Ensure a low-impedance path to ground for the ESD currents.
- Position ESD protection devices close to the point of entry
- When protecting high-speed lines, use ESD protection devices with low capacitance to avoid degrading signal integrity.

## RESOURCES with Links

**USB**

- How does a USB keyboard work? - Ben Eater
- How does USB work? – Ron Mattino
- How does a USB device discovery work? - Ben Eater
- Routing Requirements for a USB Interface on a 2-Layer PCB
- Can You Route Digital Signals on a 2-layer PCB Design?

**ESD**

- AN5612 - ESD protection of STM32 MCUs and MPUs
- Basics of TVS Diodes (ESD protection diodes)

# USB AND ESD PROTECTION - 2

## Capacitors

Capacitors are electronic components that store and release electrical energy, consisting of two conductive plates separated by an insulating material (dielectric). They accumulate electric charge when a voltage is applied, creating an electric field across the dielectric.

## Key Characteristics

- Capacitance (C)
- Voltage Rating
- ESR (Equivalent Series Resistance)
- Types: Common types include ceramic, electrolytic, and film.

## Applications

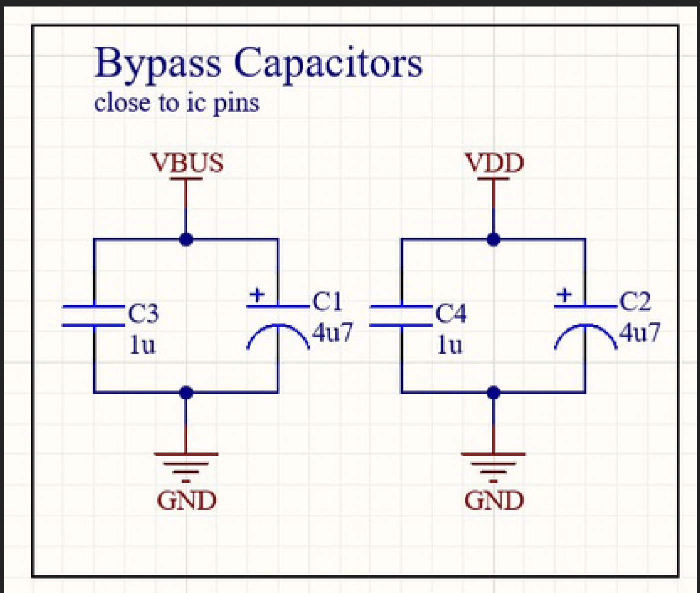
- Filtering
- Timing Circuits
- Decoupling
- Coupling
- Energy Storage

## MLCC

MLCC (Multi-Layer Ceramic Capacitors) are a type of ceramic capacitor that consists of a structure significantly increases the capacitance per unit volume, making MLCCs highly efficient and compact.

## MLCC CLASSES

- **Class I (C0G/NP0):** Very stable with low capacitance change over temperature and low loss, suitable for precision applications.
- **Class II (X7R, X5R):** Higher capacitance values but with moderate stability over temperature. Suitable for general-purpose use, including power supply decoupling.
- **Class III (Y5V, Z5U):** High capacitance with wide variation over temperature and applied voltage. Used where large capacitance is needed, but precision is not critical.




## Key Characteristics

- High Capacitance in Small Size
- Wide Capacitance and Voltage Range
- Low ESR and ESL

## TIPS AND COMMENTS

- I used Class 2 MLCC to provide filtering for power signals as well as occupying smallest area.
- In the case where I would need more stability such as an oscillator circuit, I would use Class 1 MLCC.
- Tantalum capacitors are added for further filtering and bulk capacitor as stated in the datasheet. Also, it occupies smaller are than an electrolytic capacitor.
- To select the appropriate capacitor for the project, it would be great to read different types of capacitors as it is self-evident which one to choose.
- As to selection of capacitor value, it is suggested that you follow the resources I will provide in which topics are examined by Eric Bogatin.
- Do not forget to place your decoupling caps as close to the IC pins as possible and keep the loop area small.

## Resources

- What Decoupling Capacitor Value To Use And Where To Place Them | Eric Bogatin
- The Myth of Three Capacitor Values

# CAPACITORS

# Differential Pairs

Differential pairs are pairs of electrical traces or conductors that carry signals of equal magnitude but opposite polarity. This technique is commonly used in high-speed digital and analog circuits, such as in communication interfaces (like USB, Ethernet, HDMI) and high-frequency data transmission.
In its basic form a differential pair consists of two single-ended transmission lines, containing equal amplitude but opposite polarity energy.

One of the reasons they are used is so that the circuit will ignore offsets in ground.

## Coupling

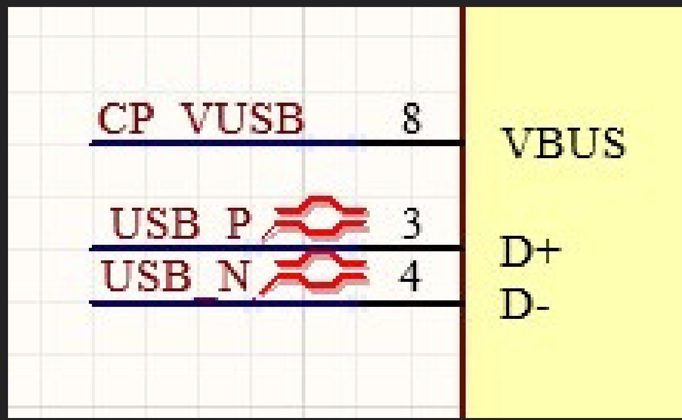
When transmitted in a PCB, Most of the coupling isn't between the lines. 85 to 90 percent of the coupling from each of these lines is to the plane below. If there is a pair of planes on either side, then it will to that pair of planes.

## Differential Impedance

The differential impedance defined by two times the odd mode impedance. Odd mode impedance is equal to characteristic impedance minus Z coupling. Use a 3D Field Solver to resolve impedance of differential pairs.

## Keep in Mind

·There are two things to keep in mind. First, having them tightly coupled doesn't help lower crosstalk if other things are brought terribly close to them at all. Keep other lines away from the differential pairs by at least two- or three-times height above the plane. Second, you can't route other things terribly close to differential pairs. Because what crosstalk will do is offset the crossing point.




Changing layers with a differential pair is either with a pair of vias or a single return via

## Length-Matching

Skew is set up by the 20 to 80 percent region that of the rising and falling edge and skew calculations give a very generous skew limits. You shouldn't ignore length matching, but it is not as critical as every application note leads you to believe. Rick Hartley says he never in his life length-matched the two lines of a differential pair including at five GHz

## Neck it Down

Where you must neck the pair down, don't worry about its impedance as long as the impedance discontinuity you create in the line by necking it down is short.

## Resources

The notes provided are taken from a Altium video, Rick Hartley as Keynote Speaker

- **What your Differential Pairs Wish You Knew with Rick Hartley**
- **What Are Differential Pairs and Differential Signals?**

# DIFFERENTIAL PAIRS

# UART

**UART (Universal Asynchronous Receiver/Transmitter):**

- Defines a protocol for exchanging serial data between two devices.
- Uses only two wires for transmission (TX) and reception (RX) plus a ground connection.

**Communication Modes:**

- *Simplex:* Data is sent in one direction only.
- *Half-Duplex:* Each side can transmit, but only one at a time.
- *Full-Duplex:* Both sides can transmit simultaneously.

**Data Transmission**:

- Data is transmitted in the form of frames.
- Frames contain the structured format and content for the data being sent.

# Frame Format

**Start Bit:**

- Signals the beginning of a new data frame. Typically, a single low bit (0) is sent, indicating the start of data transmission.

**Data Bits:**

- Represents the actual data being transmitted. Can vary in length, commonly 5 to 9 bits (most commonly 8 bits).

**Parity Bit (Optional):**

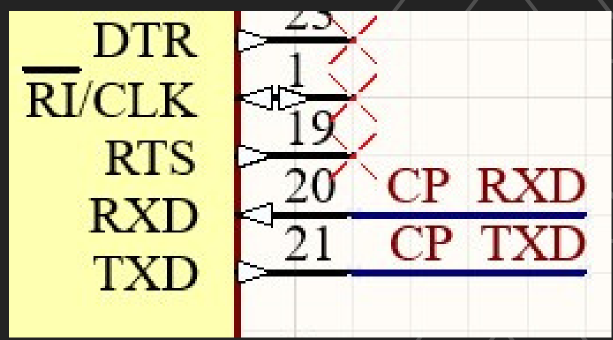
- Used for simple error checking. Can be set to even, odd, or none (no parity). Helps to detect errors in the transmitted data.

**Stop Bit(s):**

- Signals the end of the data frame. Typically, one or two high bits (1) are used. Ensures the receiver has time to process the previous frame and prepare for the next one.

# Note on UART vs RS232 vs USB

Do not forget that UART is a communication protocol so it deals with how the data format should be, UART protocol doesn't define specific voltages or voltage ranges for these levels and RS-232 or RS-485 is an interface, and they deal with physical structures such as connector type, pin arrangement, cable length, voltage levels. USB is both a protocol and an interface, so it specifies both the format and the physical structure




# UART

# REVERSE POLARITY PROTECTION

Reverse polarity protection is a circuit or mechanism designed to prevent damage to electronic devices or circuits when the power supply is connected with the wrong polarity. In electronic circuits, voltage sources usually have a specific polarity, meaning one terminal is positive and the other is negative. If the voltage source is connected incorrectly, it can lead to damaging consequences, such as blowing fuses, damaging components, or causing malfunction.

## METHODS

### Diode-based Protection

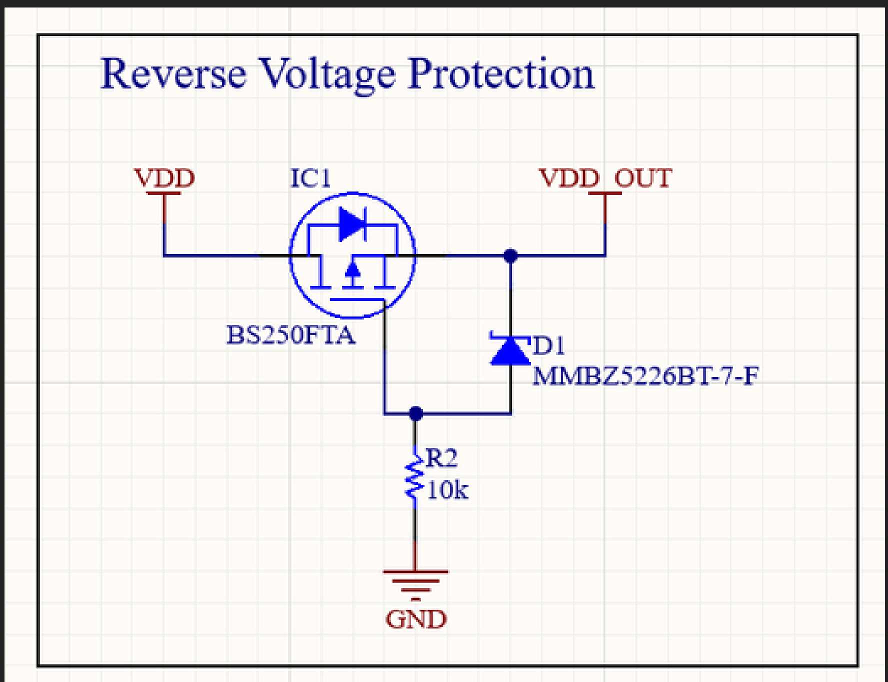
This is one of the simplest methods, where a diode is placed in series with the power supply. The diode conducts current only in one direction, blocking it in the reverse direction, effectively protecting the circuit. However, it comes with a voltage drop across the diode, which might be undesirable in some applications.

### P-Channel MOSFET

A P-channel MOSFET can be used as a reverse polarity protection device. When the polarity is correct, the MOSFET conducts and allows current to flow through the circuit. However, if the polarity is reversed, the MOSFET turns off, blocking the current flow and protecting the circuit.

### Schottky Diode with PTC Fuse

This method combines a low forward voltage drop Schottky diode with a resettable polymeric positive temperature coefficient (PTC) fuse. The diode prevents reverse current flow, while the PTC fuse limits the current in case of reverse polarity, and it resets automatically once the fault is removed.




## Notes

I could have went for the diode based protection with a schottky diode but I wanted have a P-channel MOSFET based circuit protection in my belt as a designer. Additionally, keep in mind that this circuit can be chosen over diode based protection due to efficiency.

## Resources

- **Reverse Polarity Protection**
- **How to protect circuits from reversed voltage polarity!**

REVERSE POLARITY PROTECTION

## USB-UART CONVERTERS

USB UART Converters enable communication between devices with UART (serial) interfaces and USB ports. They convert serial UART data to USB data and vice versa, allowing UART-based devices to communicate with USB-equipped computers.

## Components

- USB Interface: Connects to the USB port of a computer or other USB host.
- UART Interface: Connects to the UART pins of the target device (TX, RX, and sometimes RTS/CTS for hardware flow control).
- Microcontroller/Chip: Converts data between USB and UART protocols. Common chips include FTDI FT232, Silicon Labs CP210x, and CH340.

# Chip Choice

Some options were overkill for this project due to their features, while others were not popular based on my market research of available converters. Additionally, some choices were eliminated because I had used them in another design.
Main purpose of this project is to examine what is used in hardware design and explain the why's as I did in these pages. Therefore, the final decision was to use the CP2102N.

Some useful resources for CP2102N: datasheet development kit buy

# Ferrite beads

A ferrite bead, also known as a ferrite choke or ferrite core, is a passive electronic component used to suppress high-frequency noise or interference in electronic circuits.

I wanted to explain ferrite beads along with other topics, and in some datasheets, their use was suggested. However, when I did extensive research on the topic, the community had a different opinion.

They were used back when the rise times of components were relatively slow, and in systems where a significant voltage drop wasn't a major concern.

**ferrite beads causes ringing adds inductance**

**omit the ferrites until you can prove you need them**

Steven Sandler's famous quote

**The best time to use a ferrite is never**

# USB-UART AND FERRITE BEADS