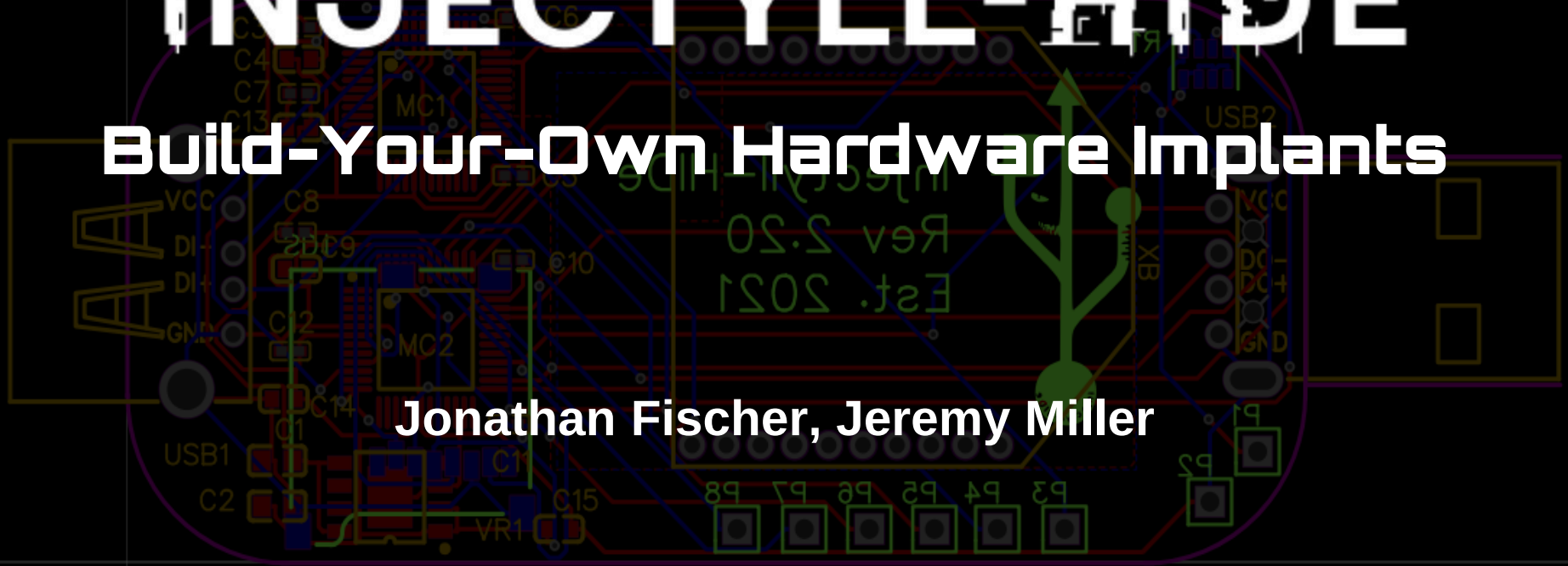
INJECTYLL-HIDE

Build-Your-Own Hardware Implants



Jonathan Fischer, Jeremy Miller

@c4m0ufl4g3

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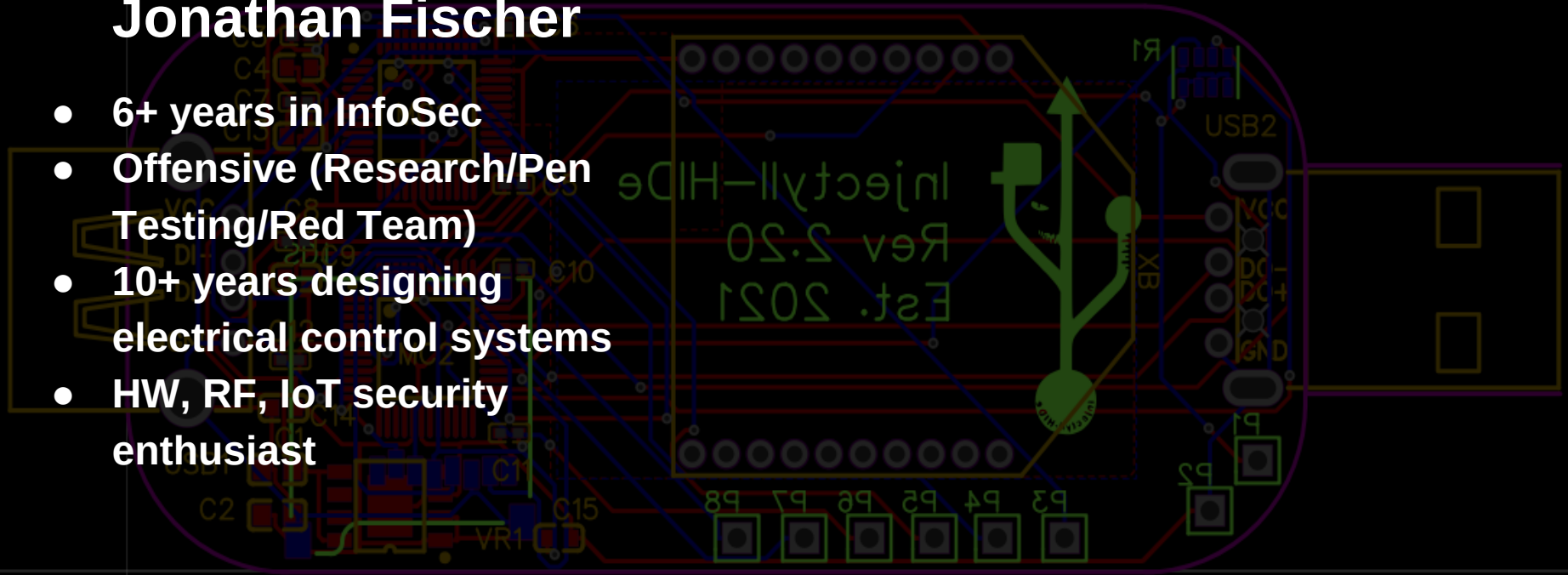
@allTheJurm

Who are we?

Jonathan Fischer

- 6+ years in InfoSec
- Offensive (Research/Pen Testing/Red Team)
- 10+ years designing electrical control systems
- HW, RF, IoT security enthusiast



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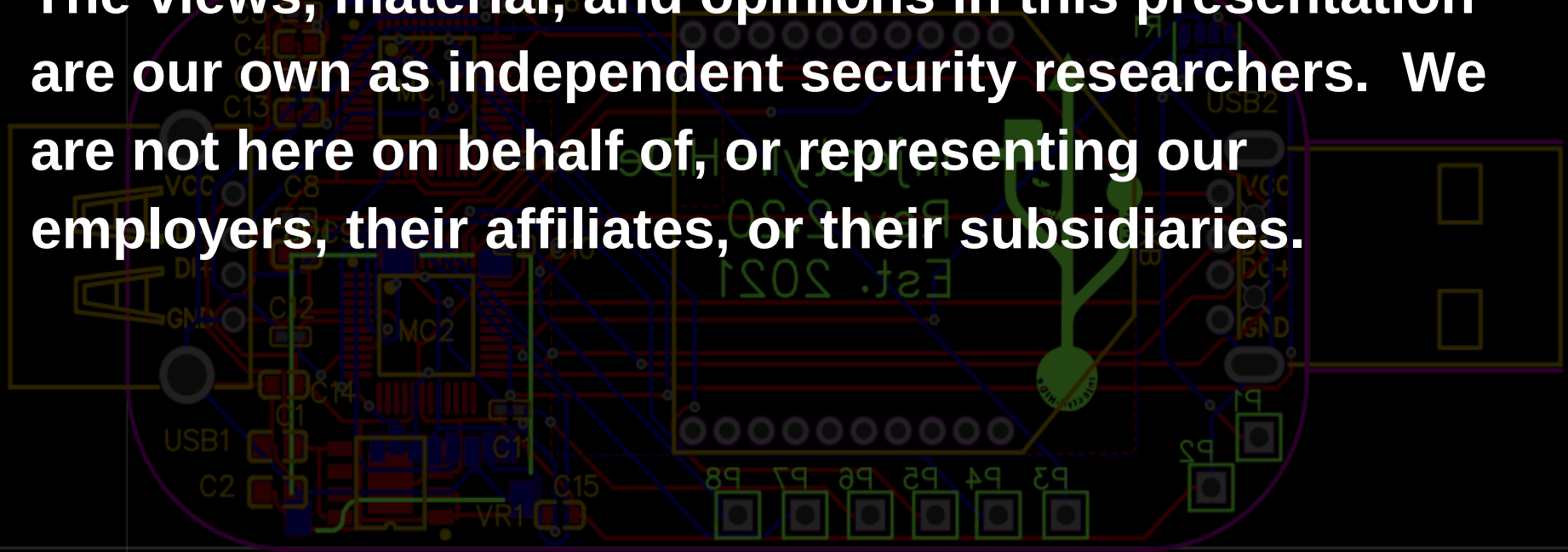
Jeremy Miller

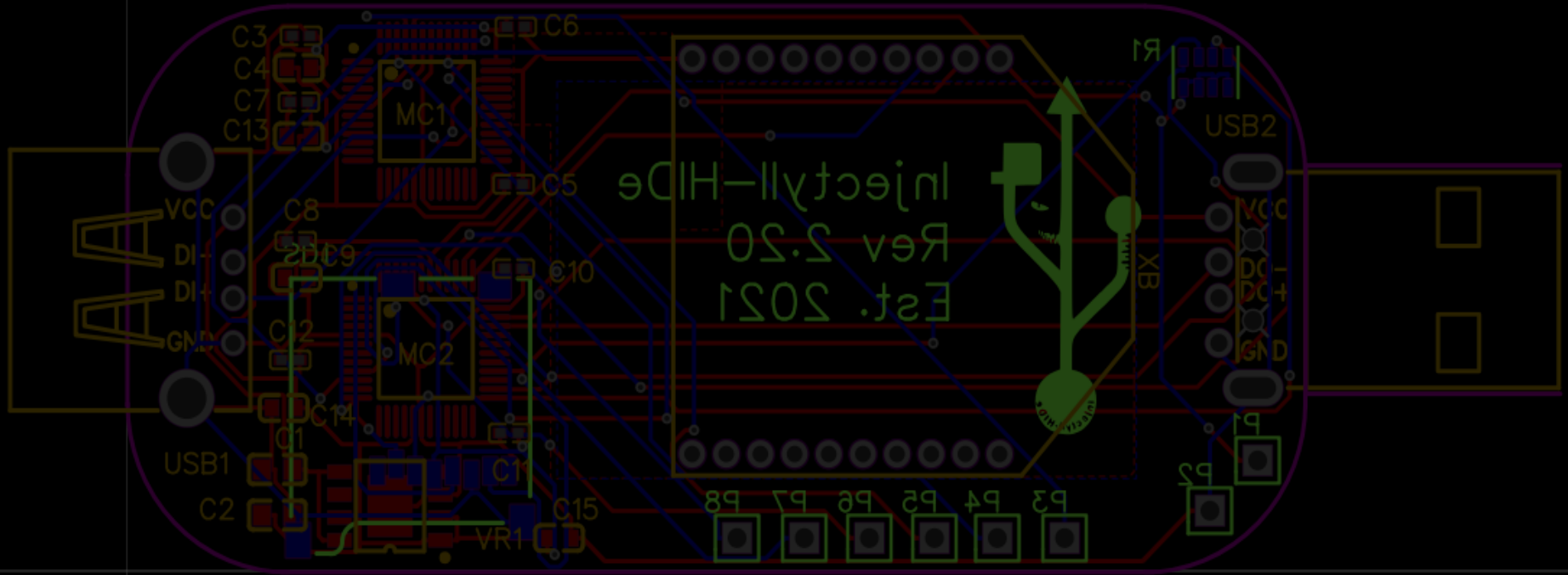
- 12+ years in InfoSec
- Red Team
- Blue Team
- Security Research
- Security Engineering
- Retail, Financial, Hosting, R&D Life Sciences.

Work Disclaimer

The views, material, and opinions in this presentation are our own as independent security researchers. We are not here on behalf of, or representing our employers, their affiliates, or their subsidiaries.



How did this come about?



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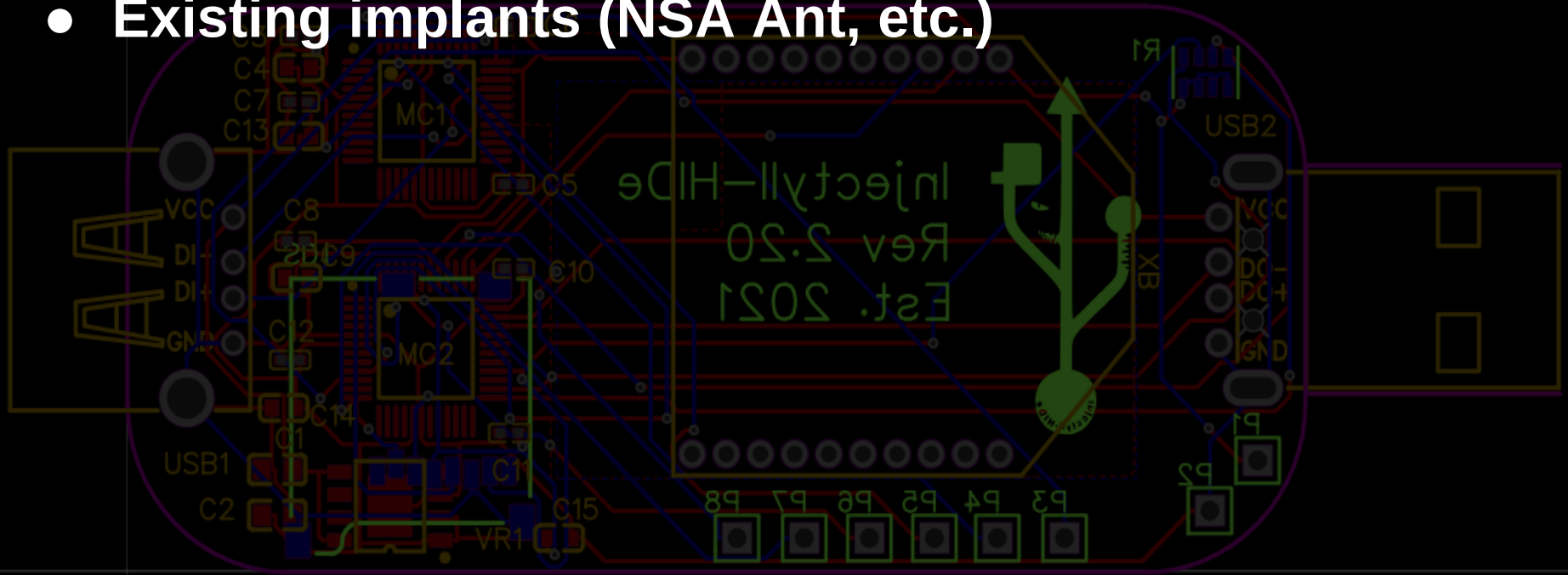
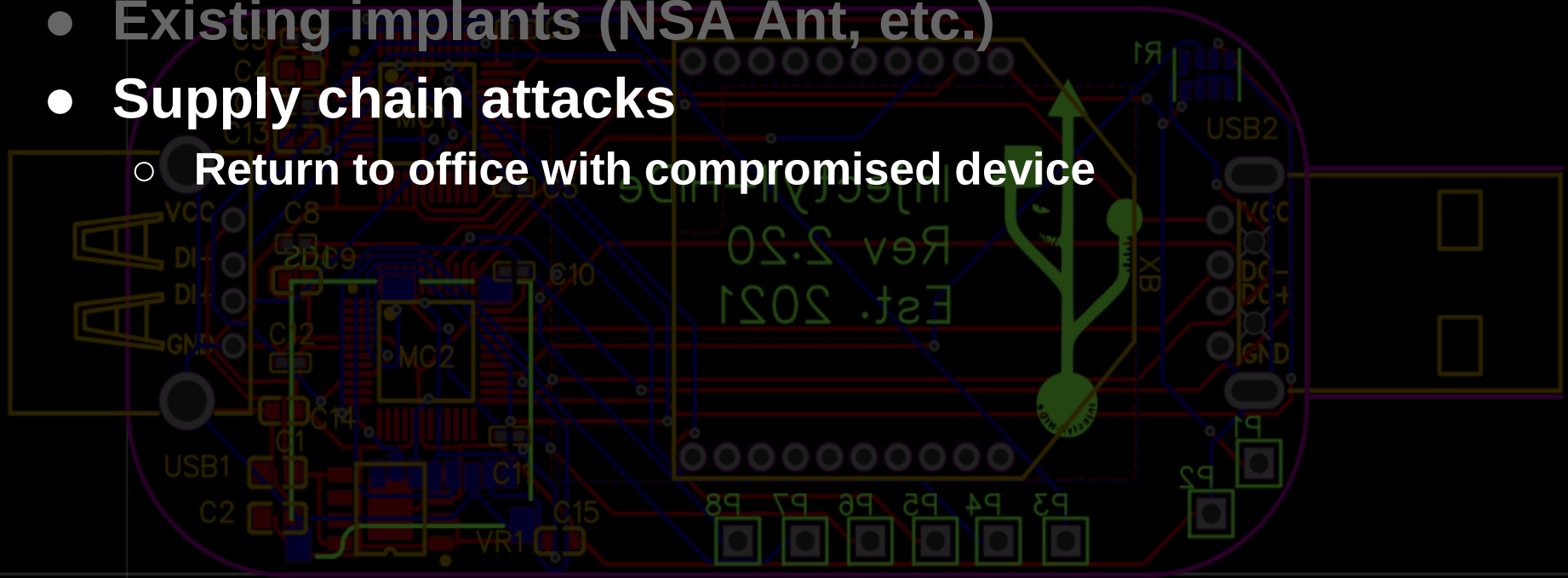
How did this come about?

- **Existing implants (NSA Ant, etc.)**



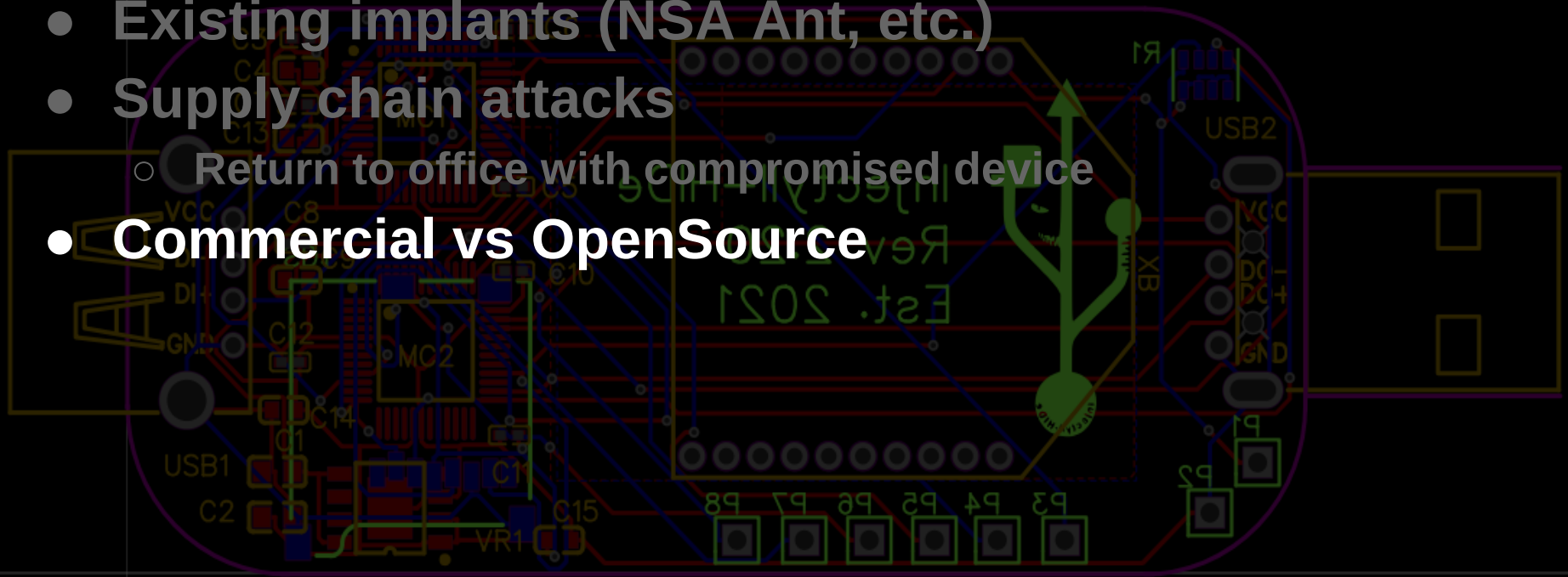
How did this come about?

- Existing implants (NSA Ant, etc.)
- **Supply chain attacks**
  - **Return to office with compromised device**



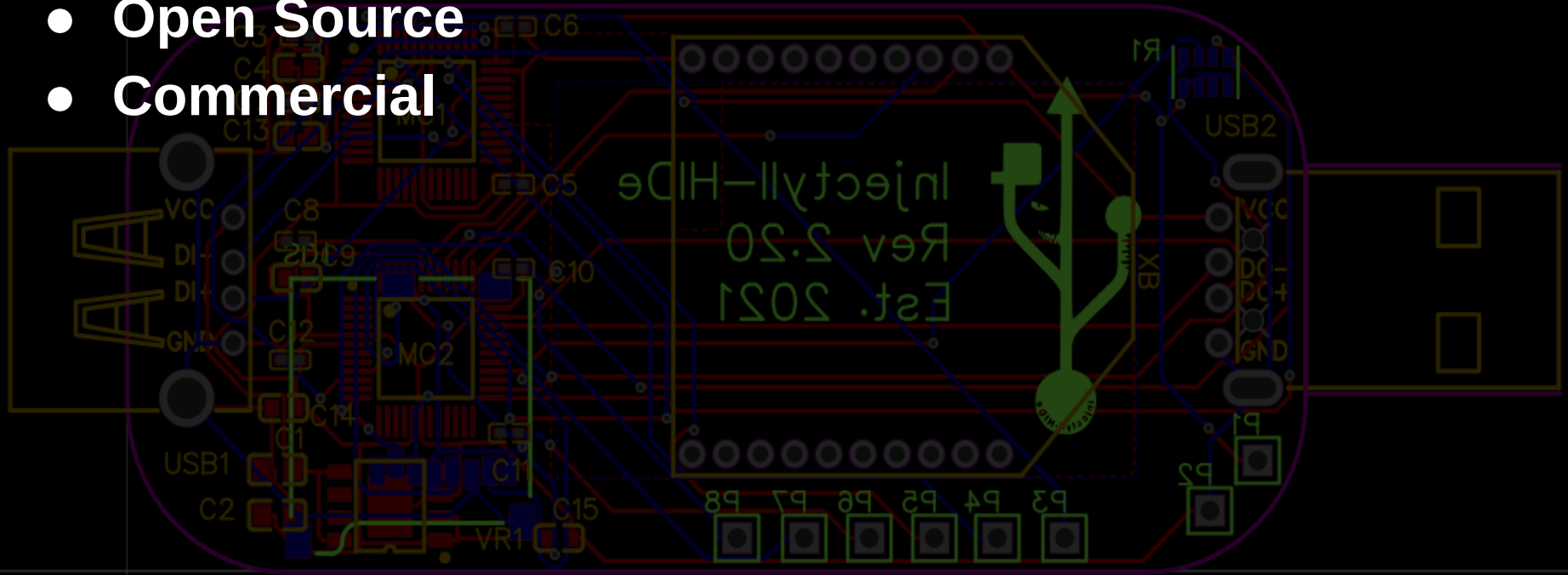
How did this come about?

- Existing implants (NSA Ant, etc.)
- Supply chain attacks
  - Return to office with compromised device
- **Commercial vs OpenSource**



What's out there now?

- **Open Source**
- **Commercial**



Commercial


Keycroc

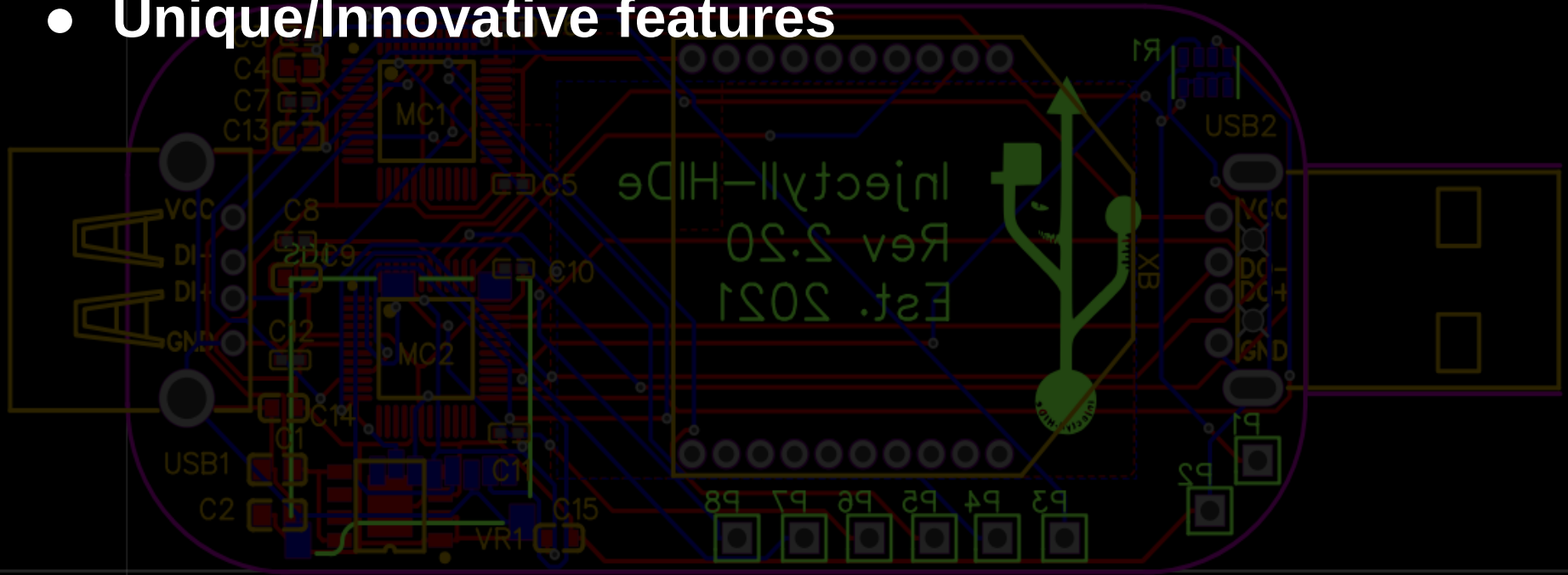

O.MG


Keelog
KeyGrabber
Module
USB


USBNinja
Ninja Pro
Module
V1.1
USB Ninja Pro ADAPTER

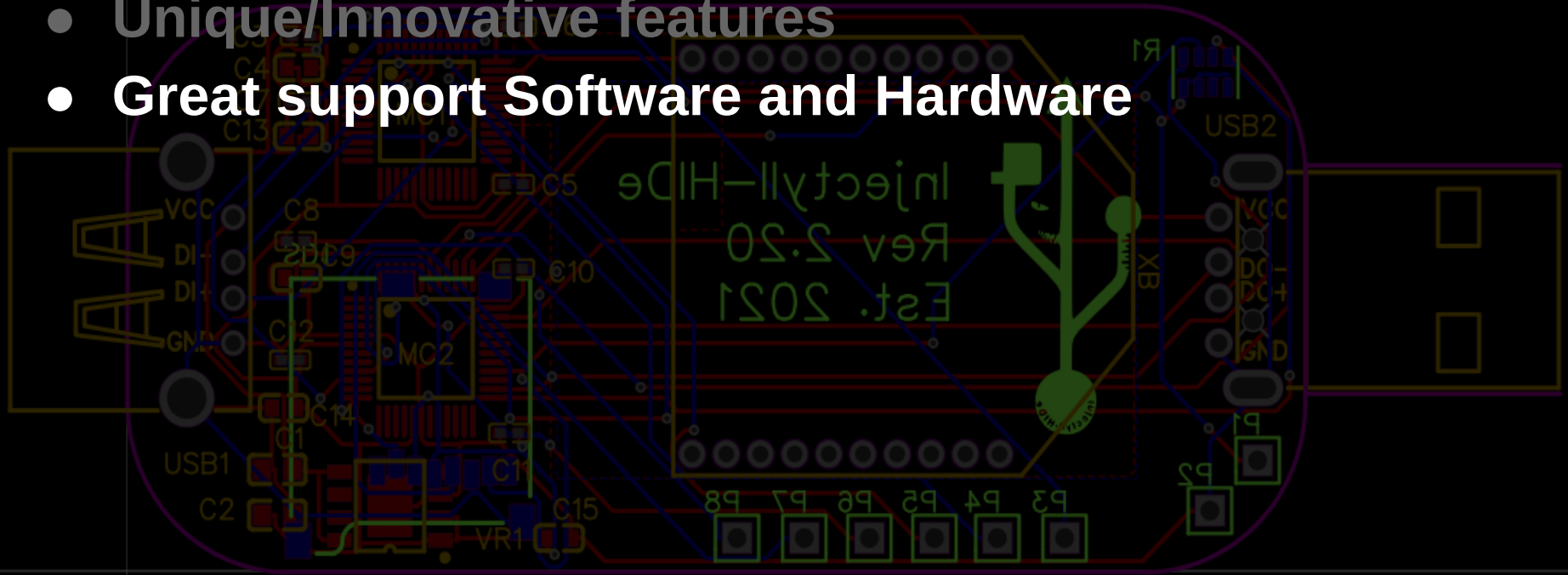
Commercial

- **Unique/Innovative features**



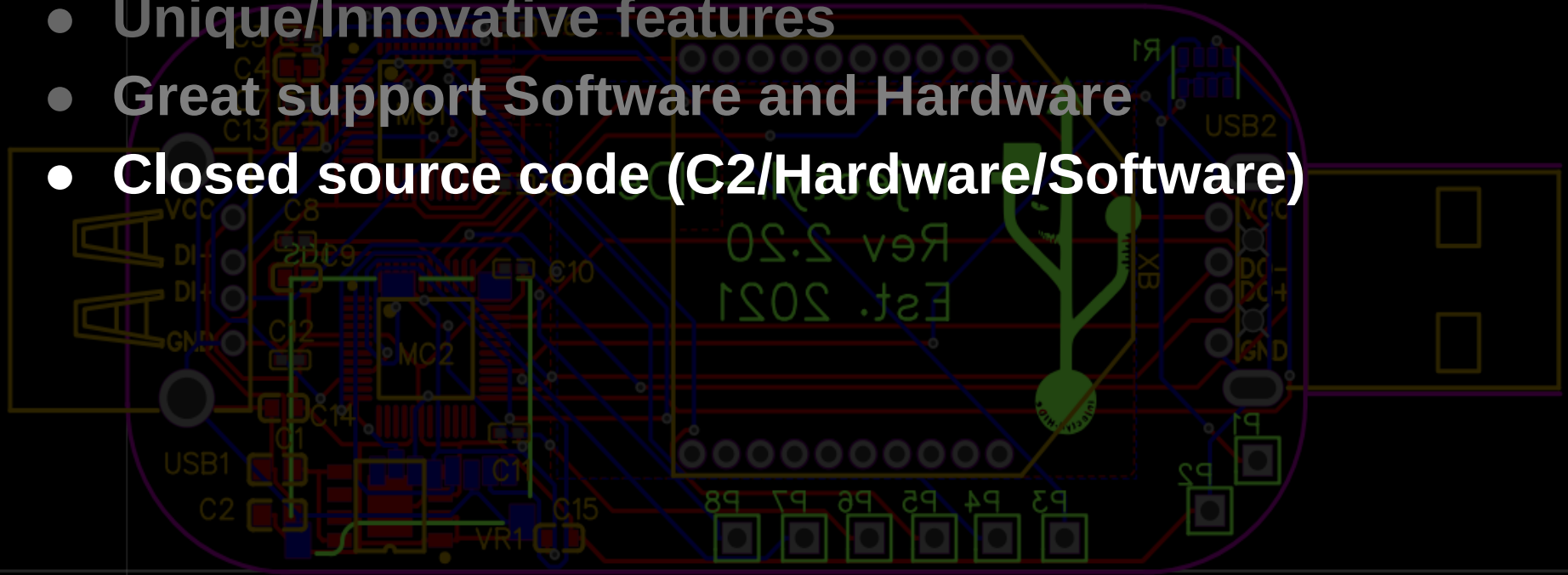
Commercial

- Unique/Innovative features
- **Great support Software and Hardware**



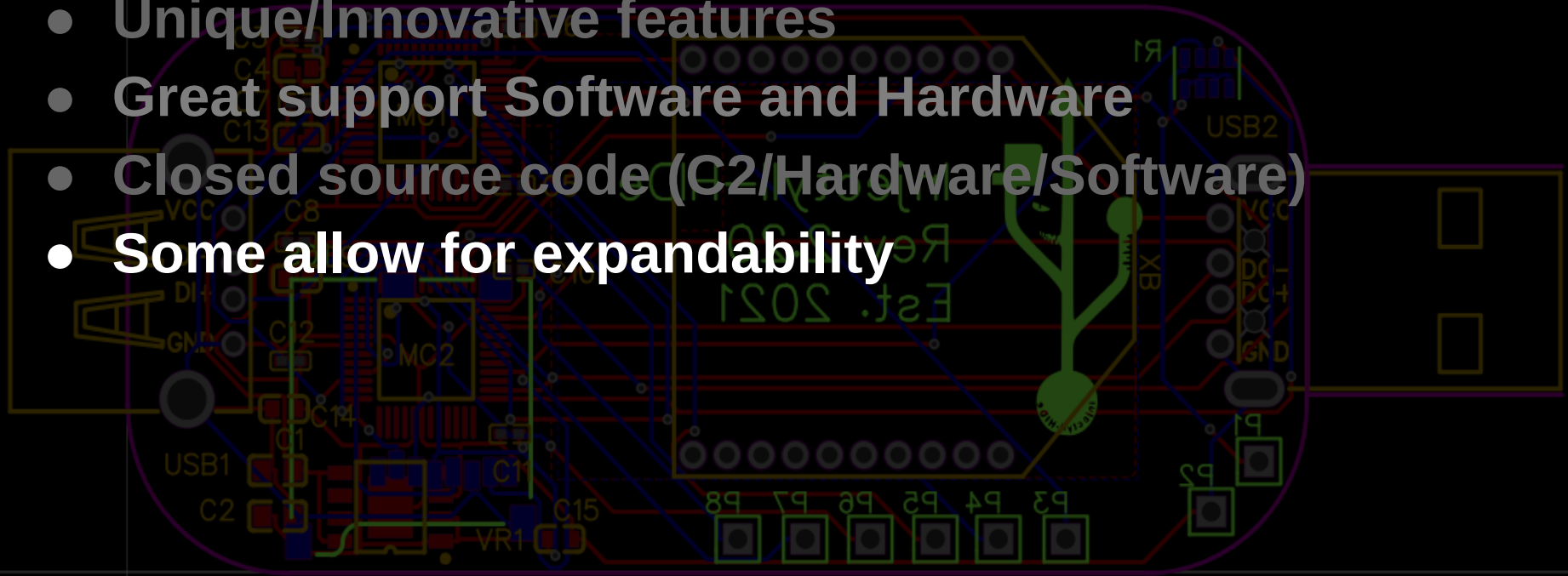
Commercial

- Unique/Innovative features
- Great support Software and Hardware
- **Closed source code (C2/Hardware/Software)**

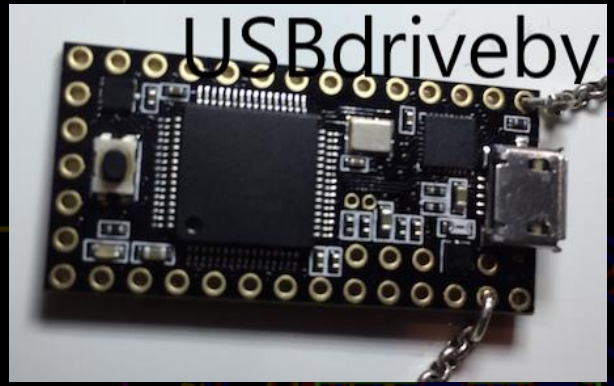


Commercial

- Unique/Innovative features
- Great support Software and Hardware
- Closed source code (C2/Hardware/Software)
- **Some allow for expandability**



Open Source



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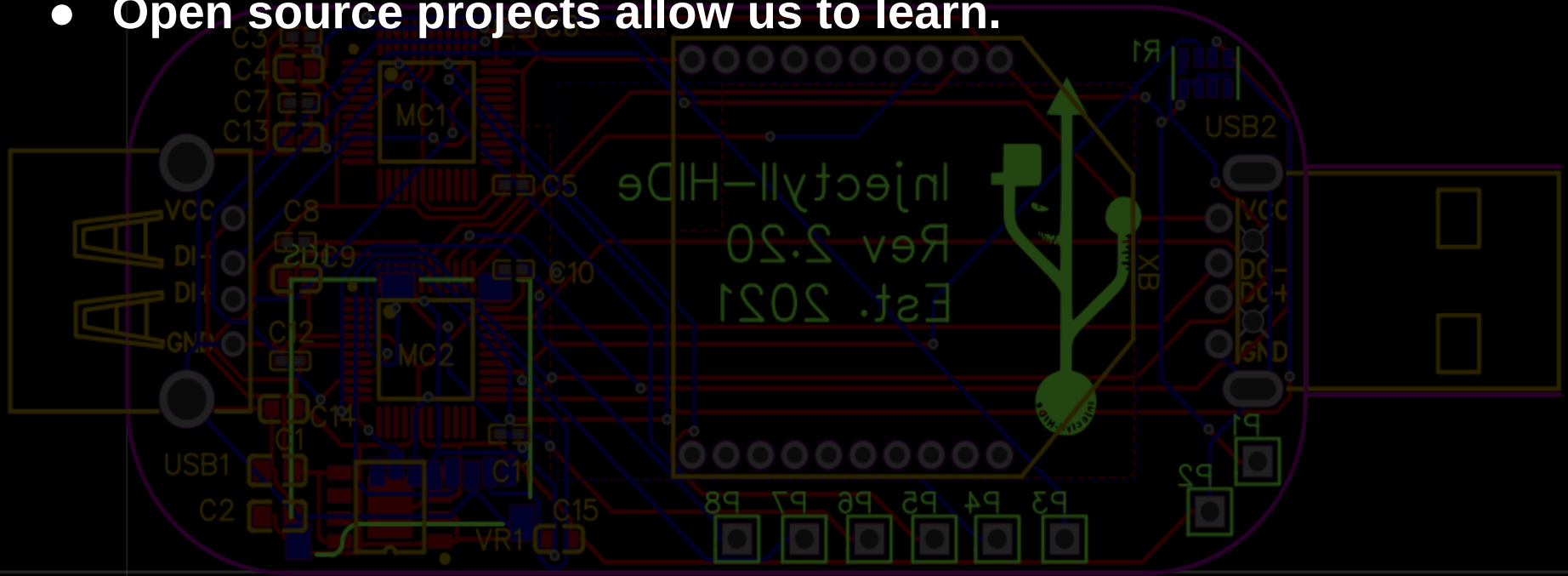
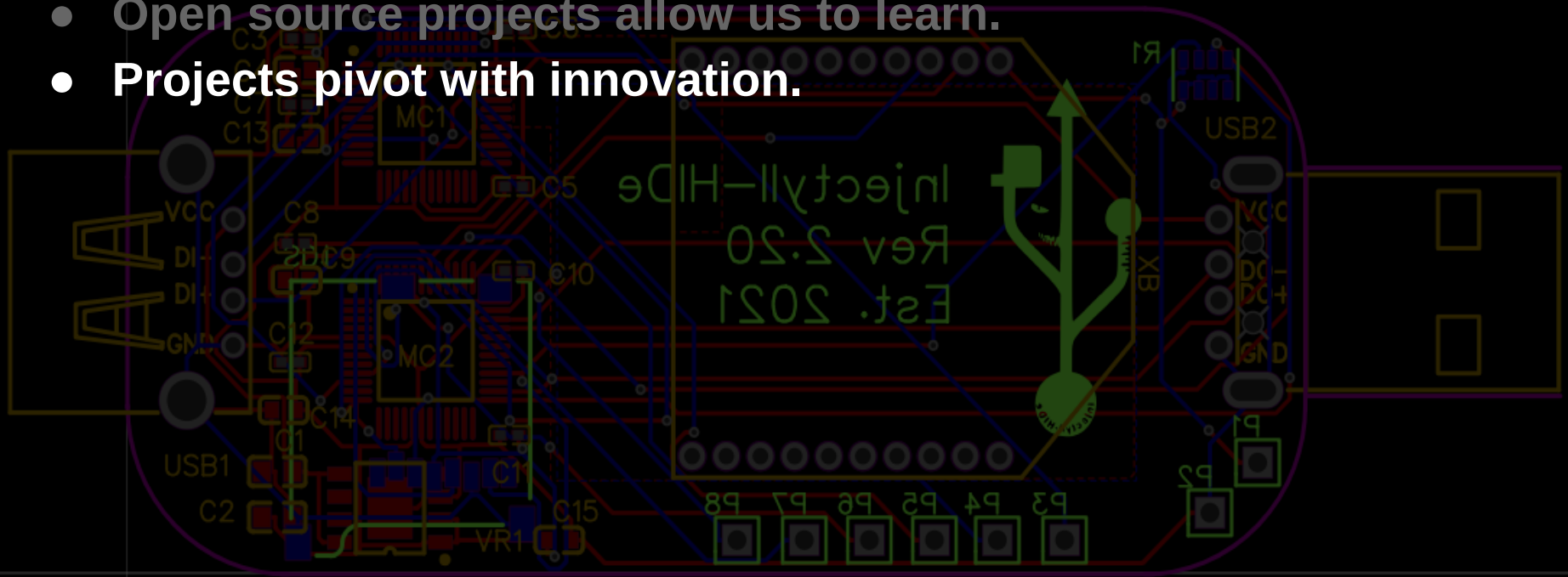
Open Source

- **Open source projects allow us to learn.**



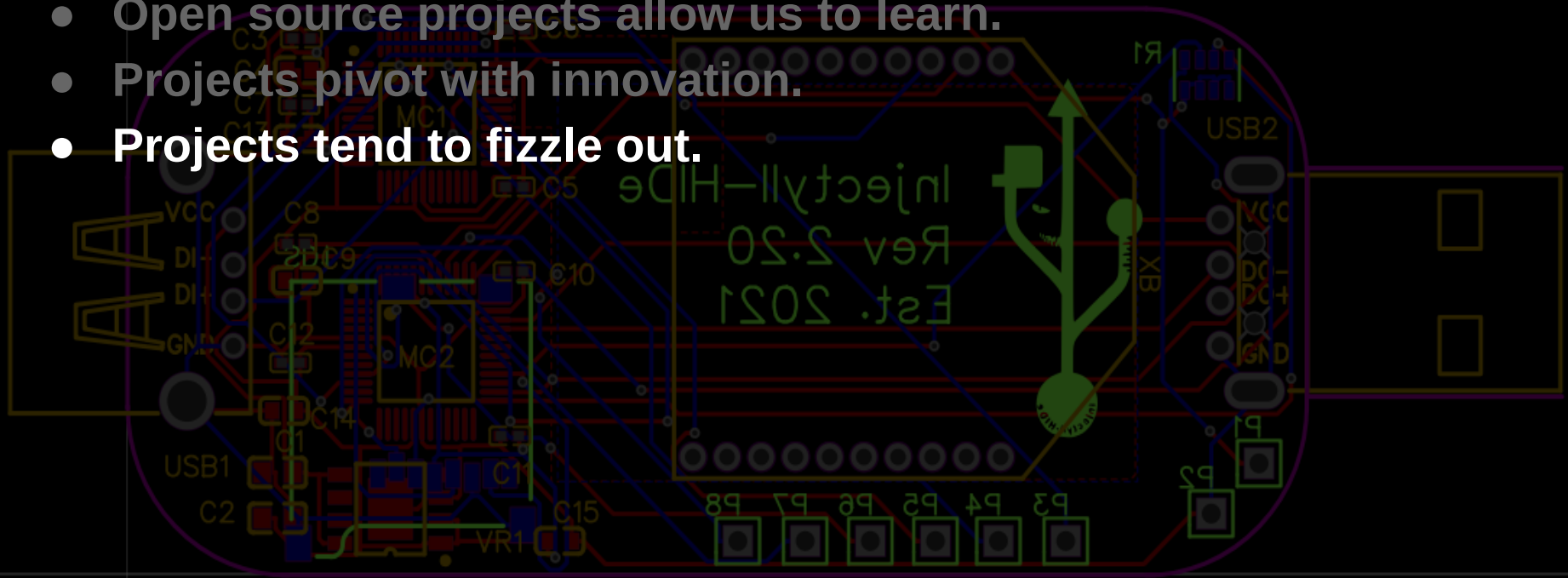
Open Source

- Open source projects allow us to learn.
- **Projects pivot with innovation.**



Open Source

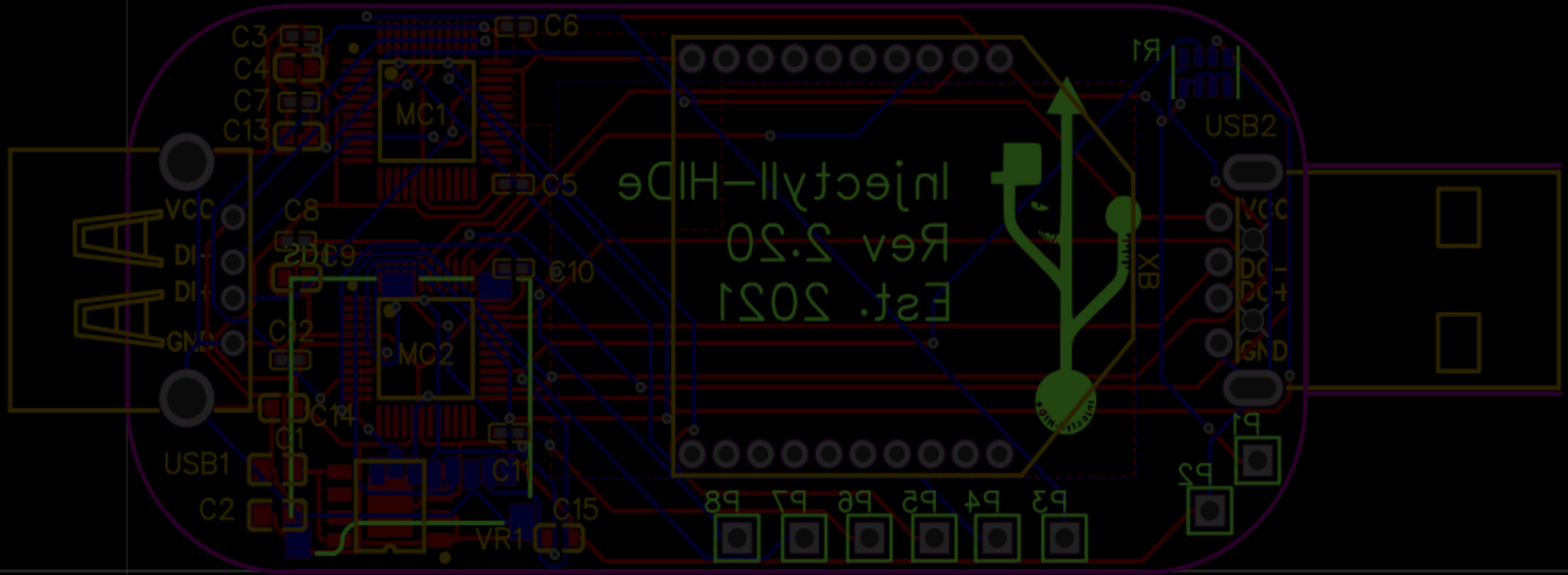
- Open source projects allow us to learn.
- Projects pivot with innovation.
- **Projects tend to fizzle out.**



Open Source

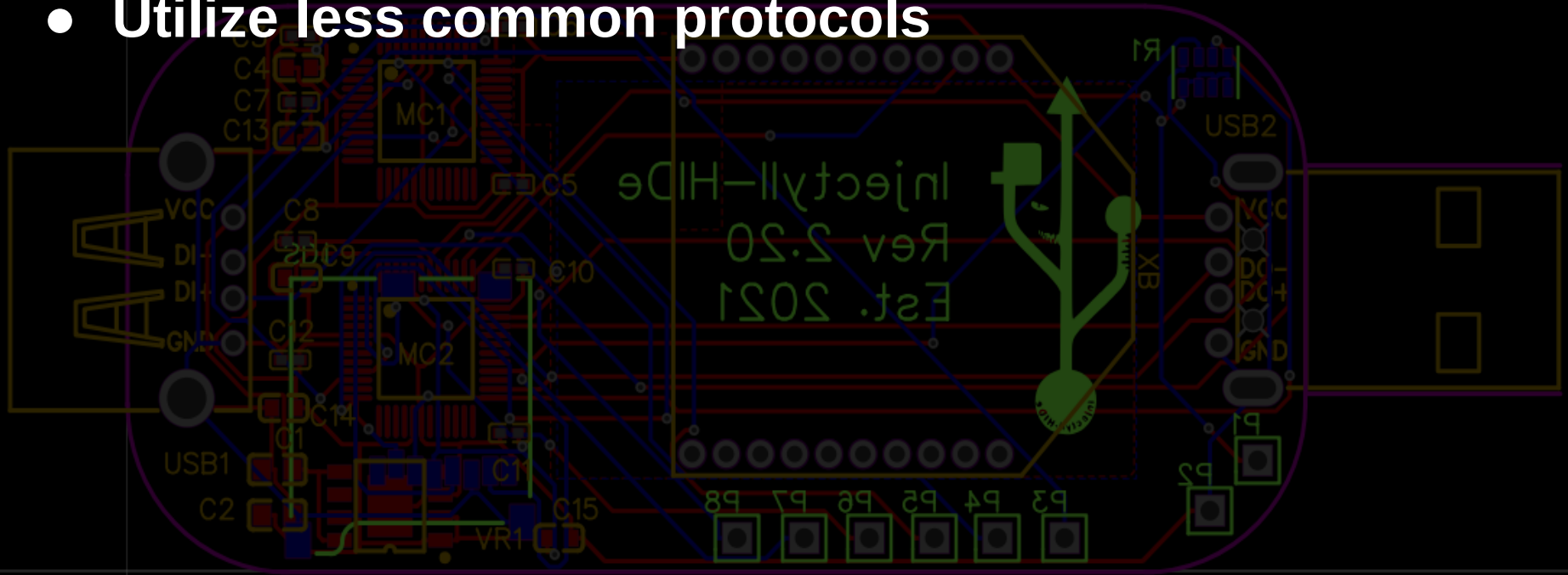
- Open source projects allow us to learn.
- Projects pivot with innovation.
- Projects tend to fizzle out.
- **Support is based on the community.**

Why create your own?



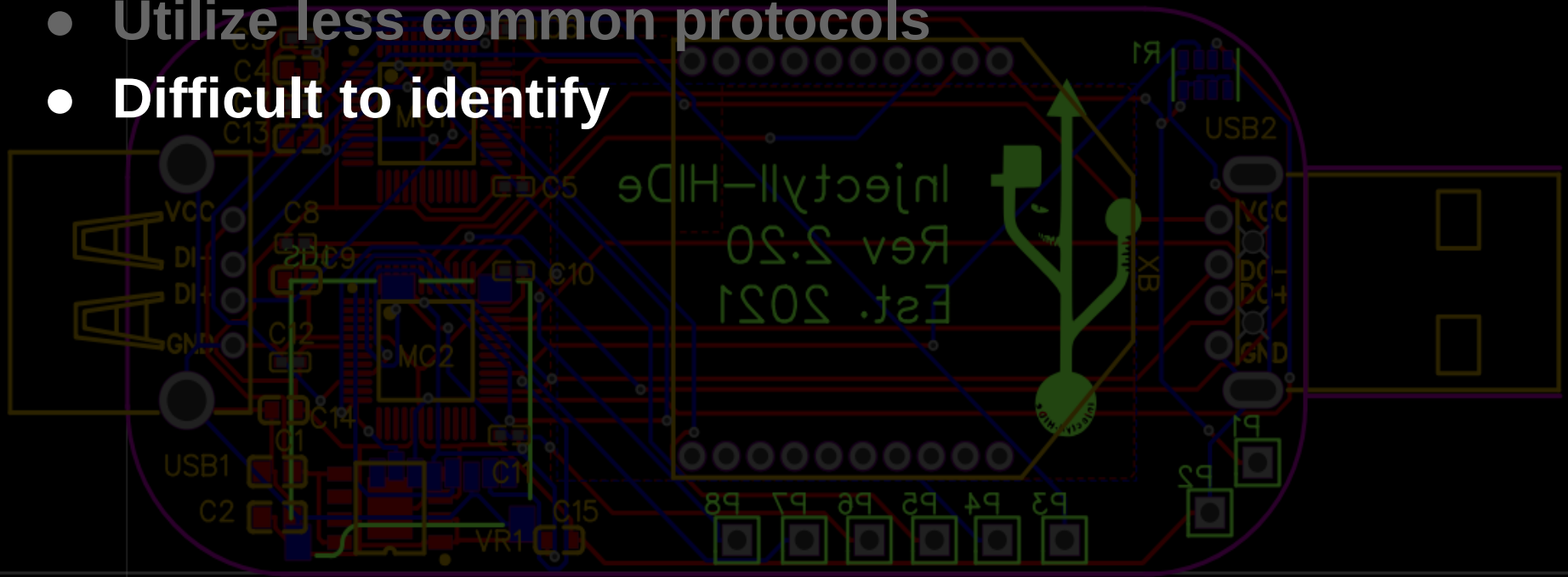
Why create your own?

- **Utilize less common protocols**



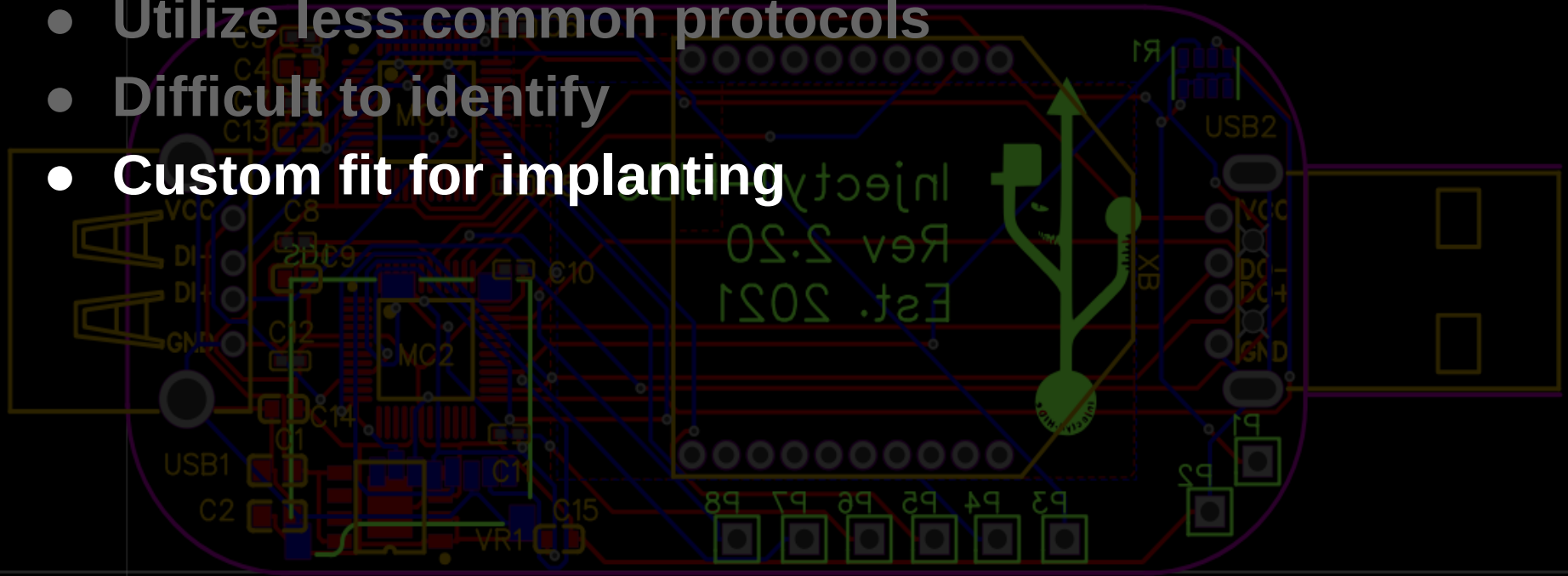
Why create your own?

- Utilize less common protocols
- **Difficult to identify**



Why create your own?

- Utilize less common protocols
- Difficult to identify
- **Custom fit for implanting**



Why create your own?

- Utilize less common protocols
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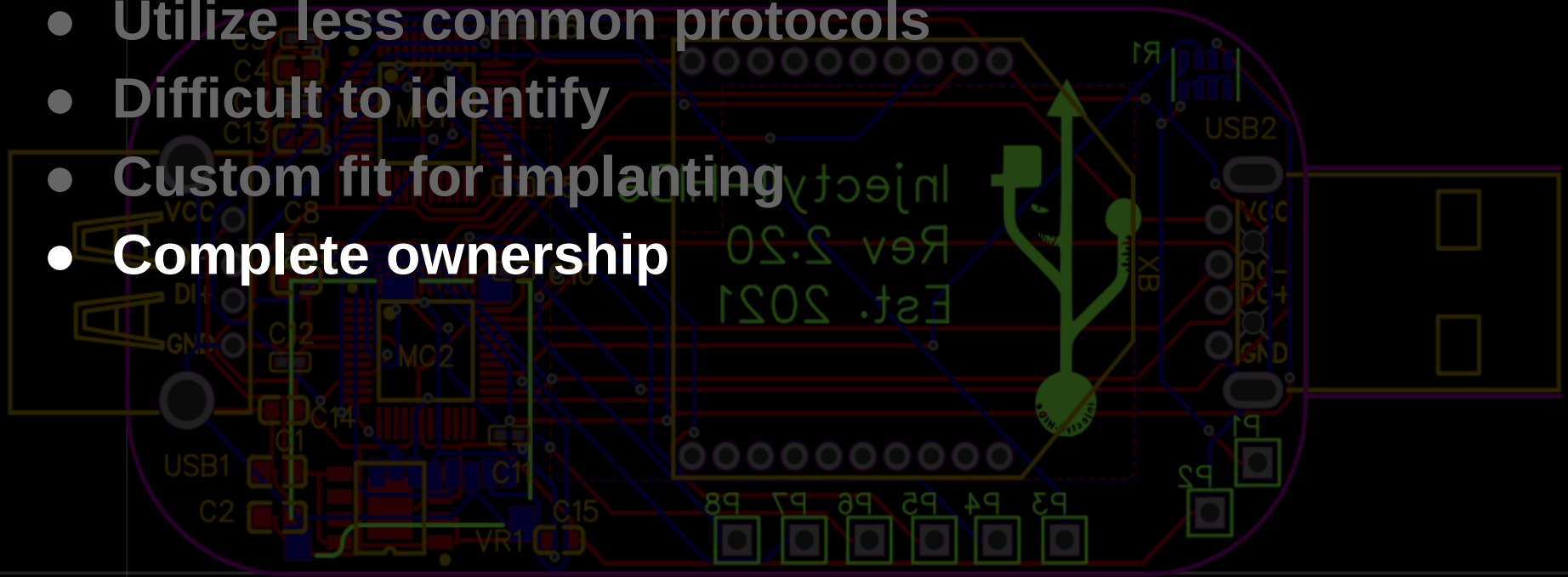
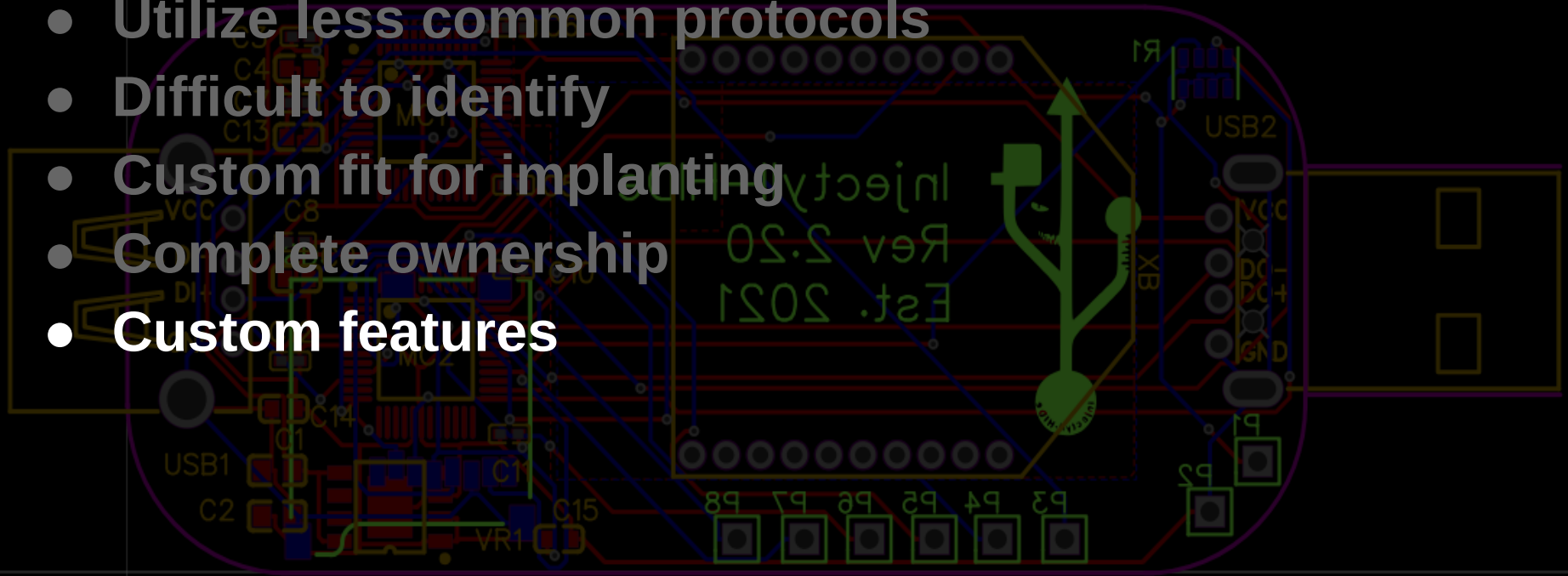
- Custom fit for implanting
- **Complete ownership**

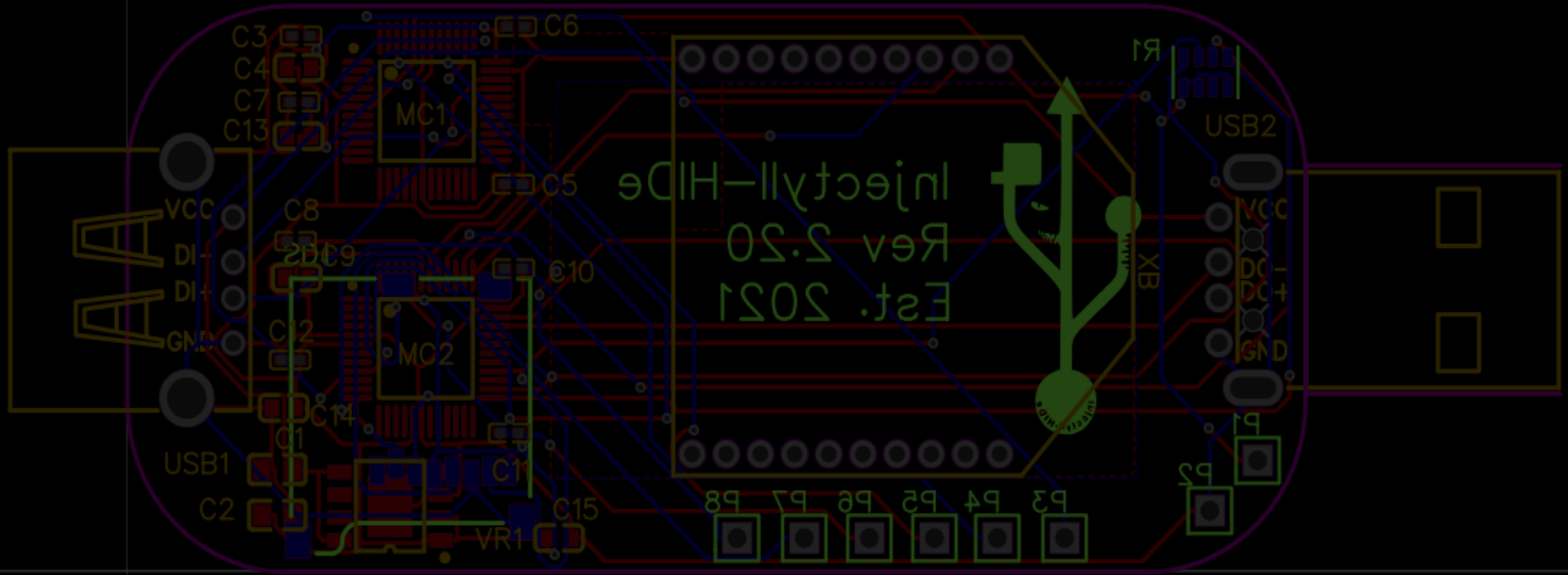


Why create your own?

- Utilize less common protocols
- Difficult to identify
- Custom fit for implanting
- Complete ownership
- **Custom features**



Demo



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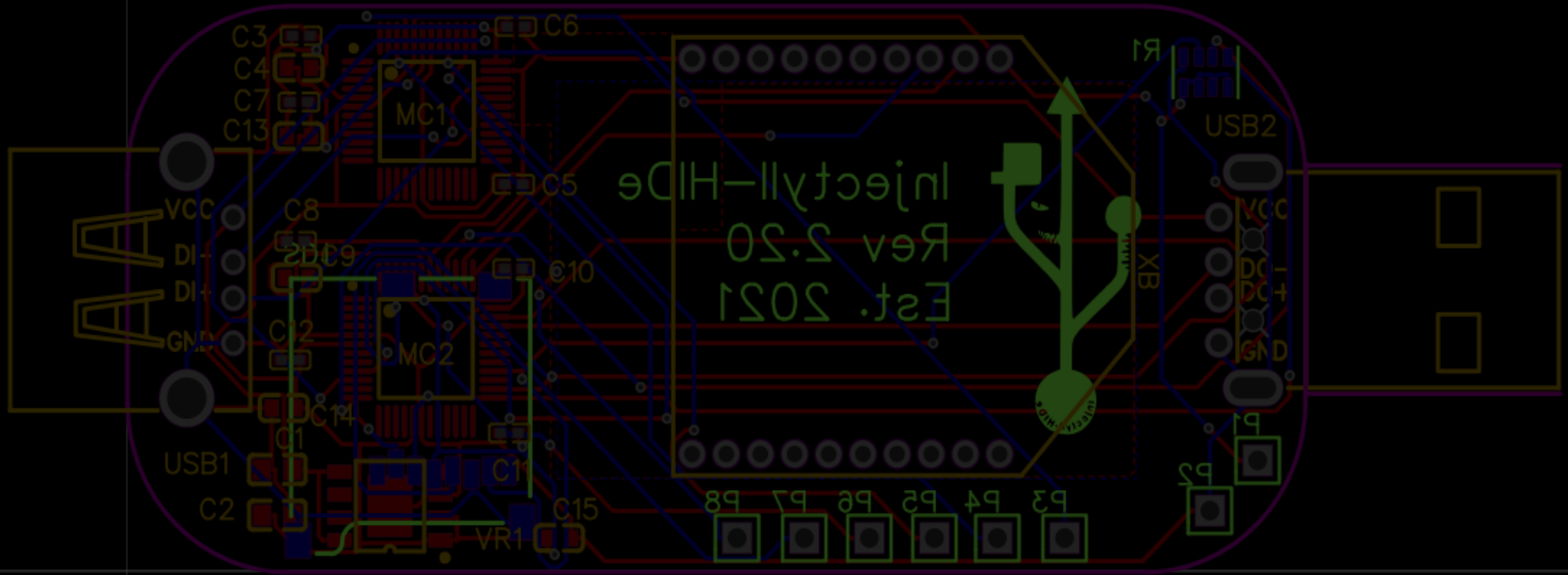
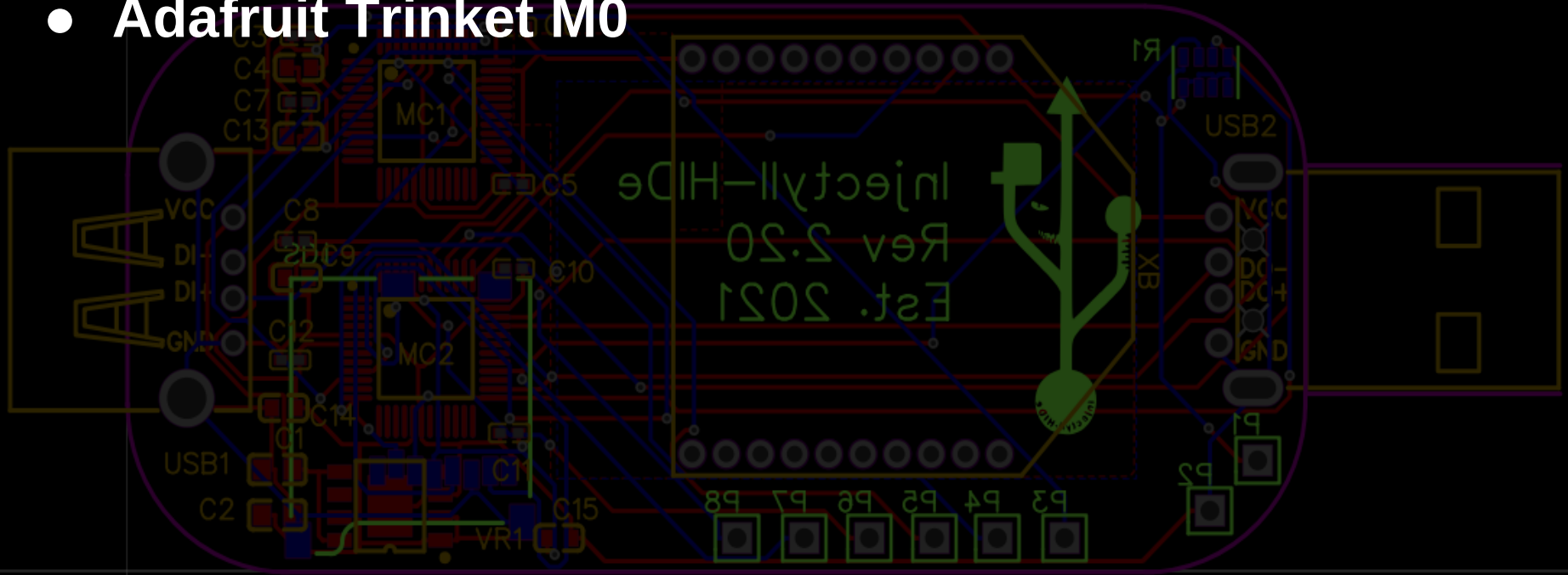
Proof of Concept



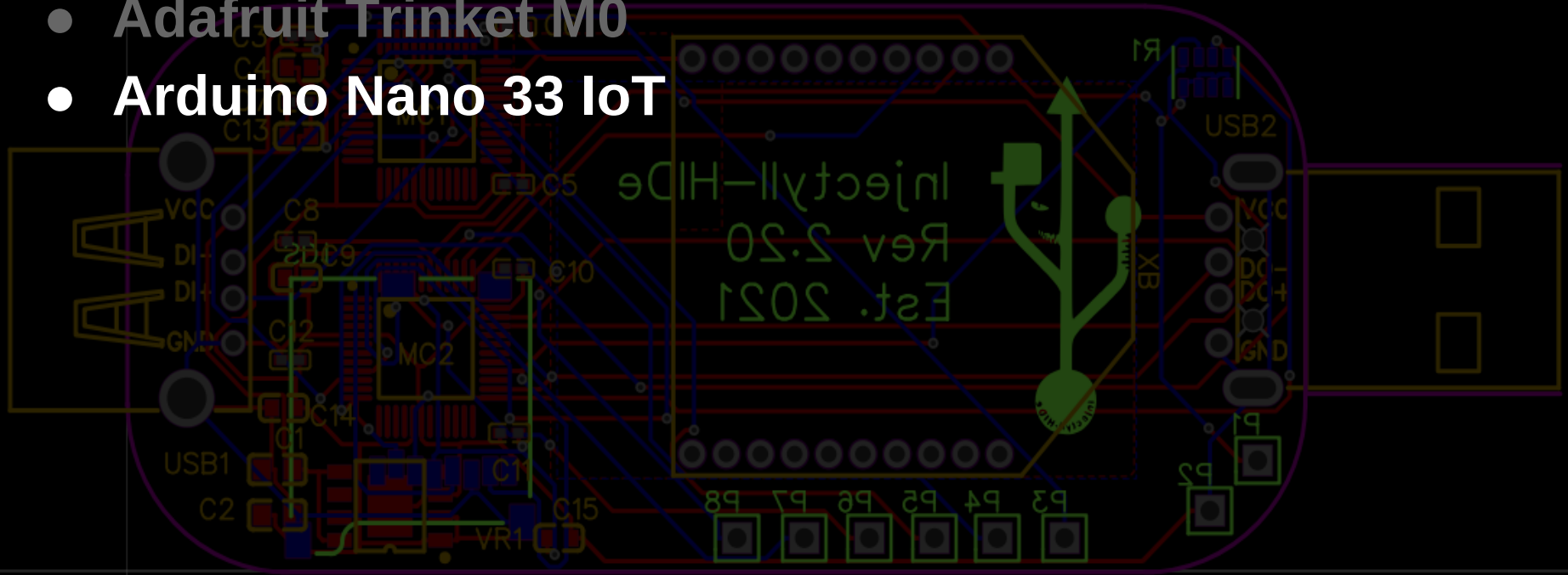
Proof of Concept

- **Adafruit Trinket M0**



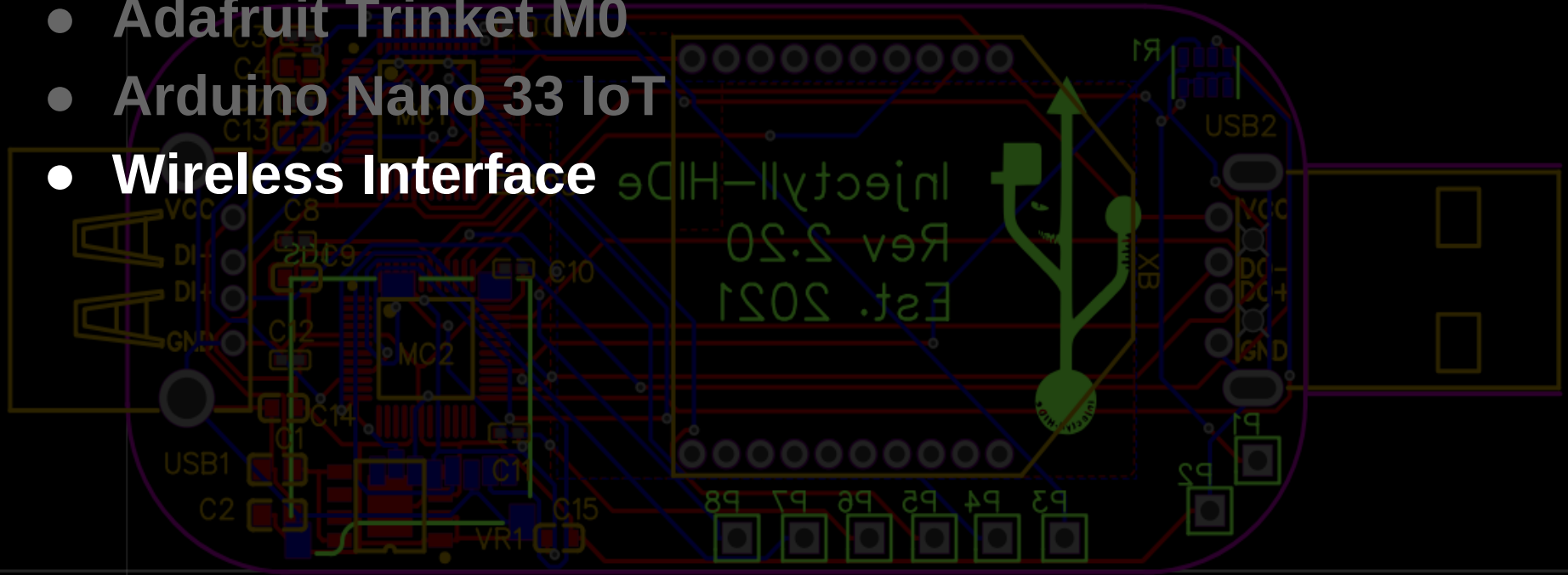
Proof of Concept

- Adafruit Trinket M0
- **Arduino Nano 33 IoT**



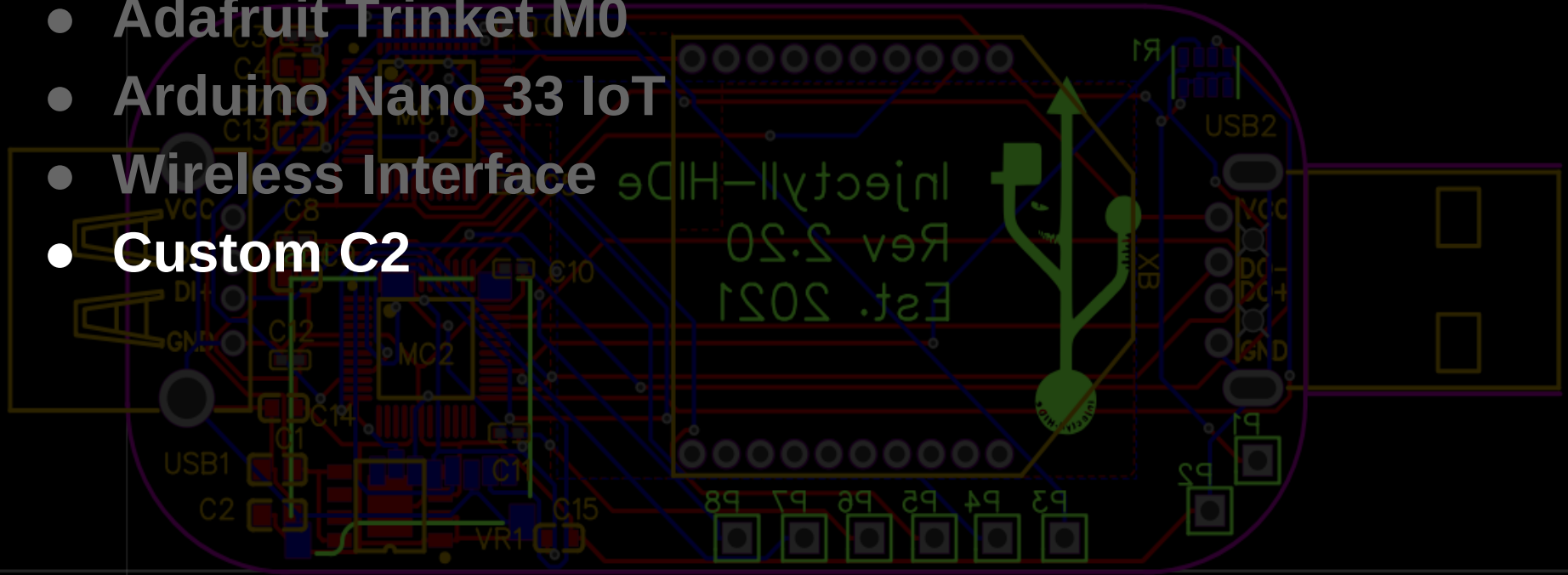
Proof of Concept

- Adafruit Trinket M0
- Arduino Nano 33 IoT
- **Wireless Interface**



Proof of Concept

- Adafruit Trinket M0
- Arduino Nano 33 IoT
- Wireless Interface
- **Custom C2**



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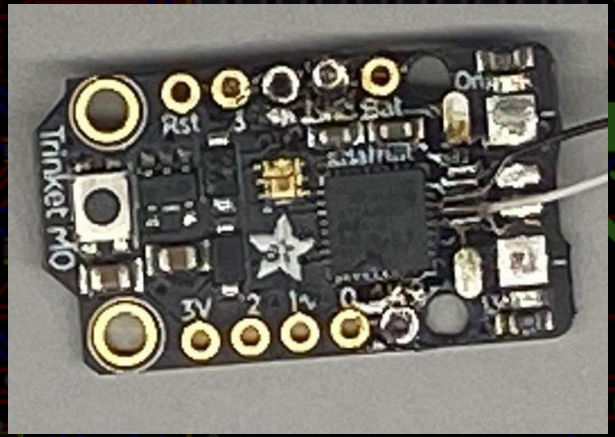

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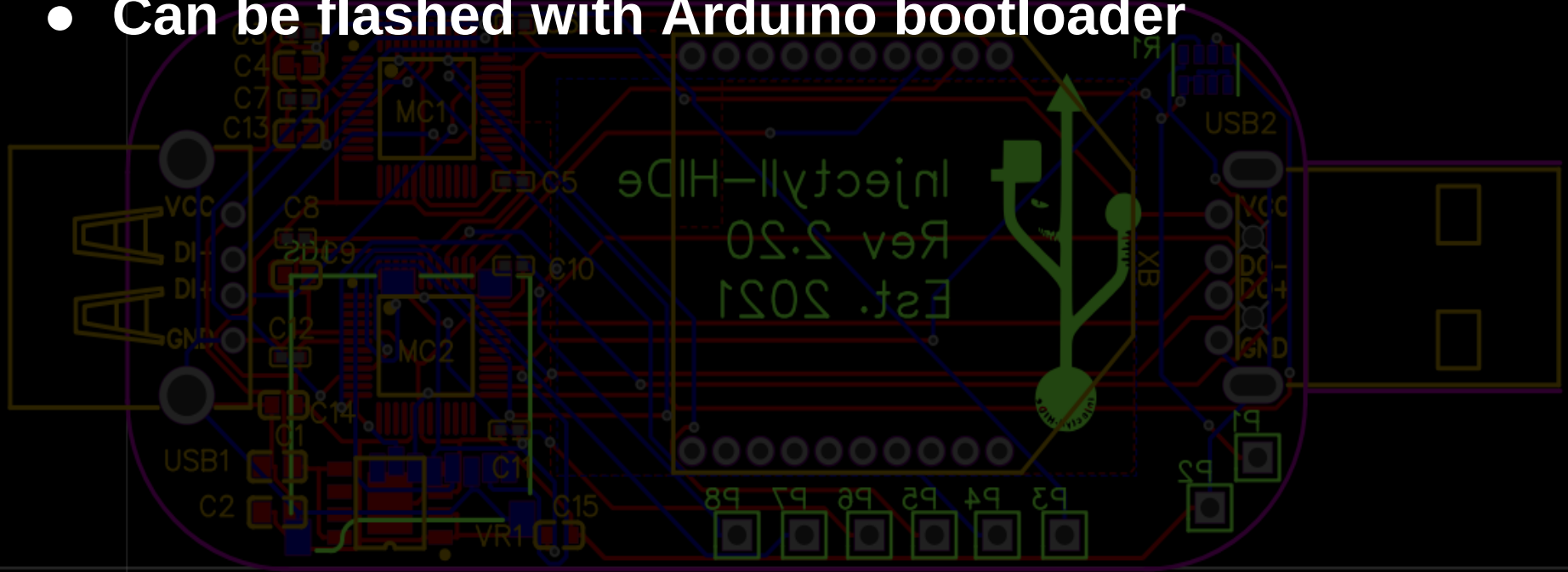
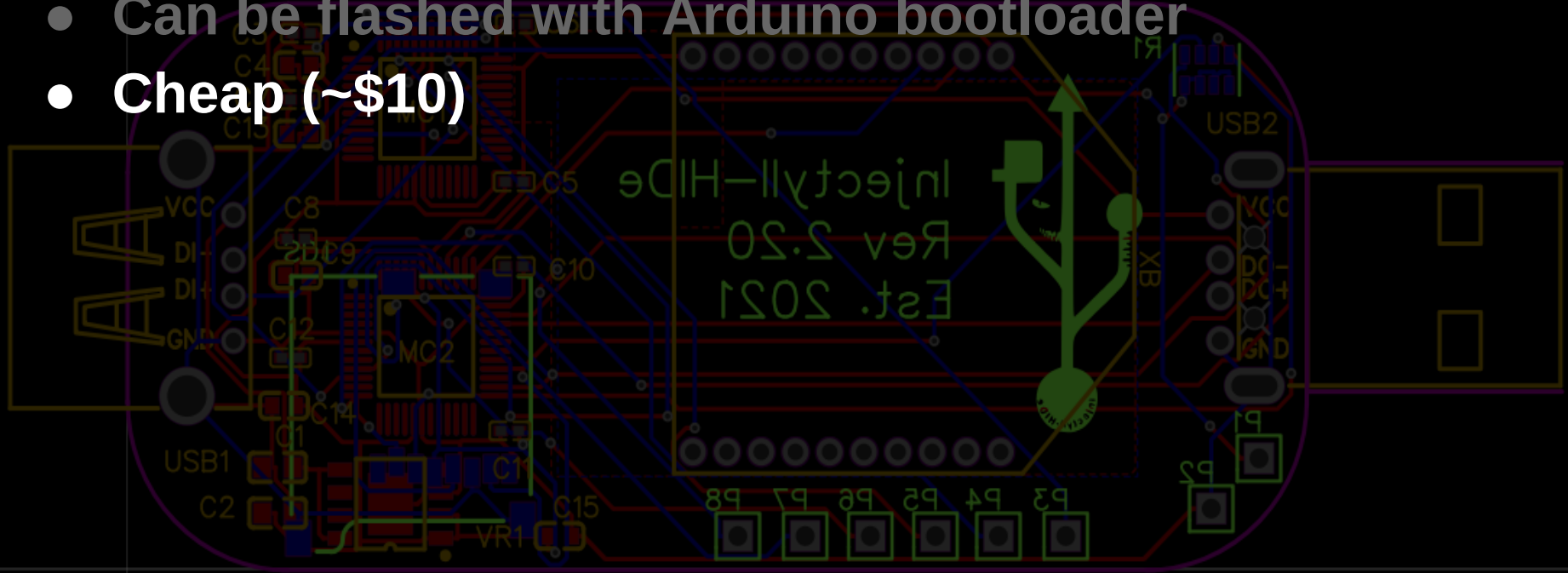
Adafruit Trinket M0

- **Can be flashed with Arduino bootloader**



Adafruit Trinket M0

- Can be flashed with Arduino bootloader
- **Cheap (~$10)**



Adafruit Trinket M0

- Can be flashed with Arduino bootloader
- Cheap (~$10)
- **Small physical footprint**

Adafruit Trinket M0

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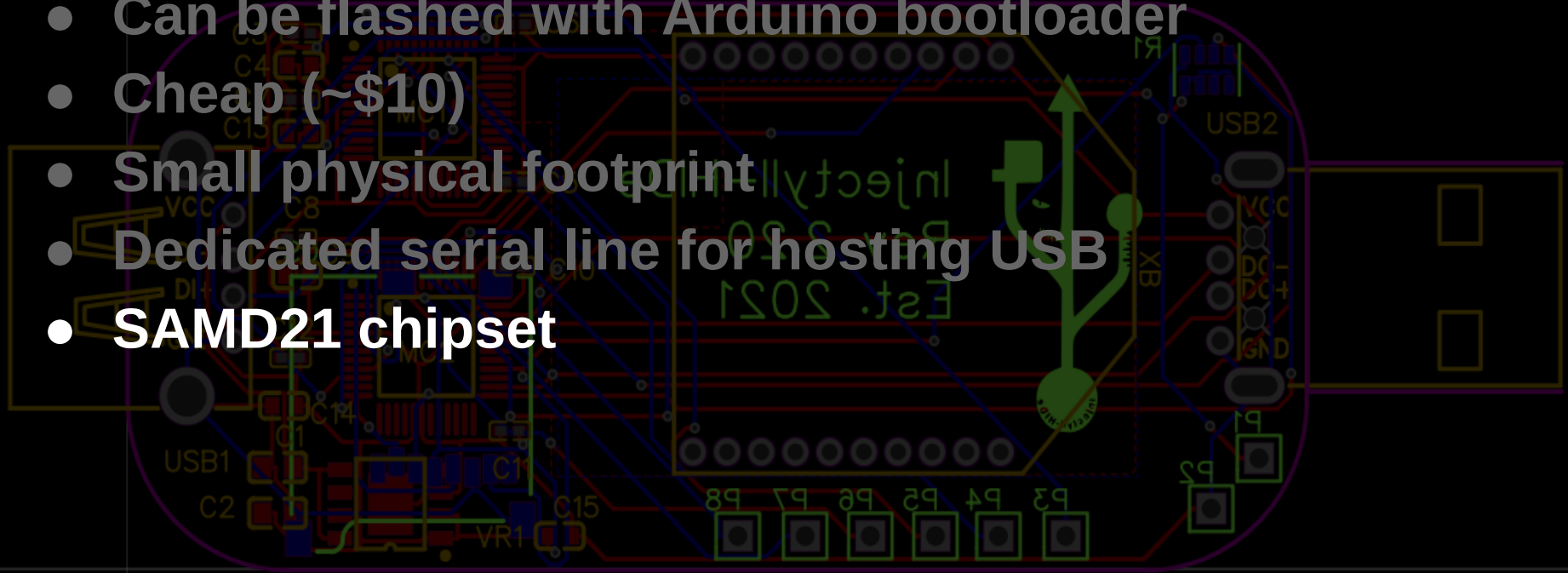
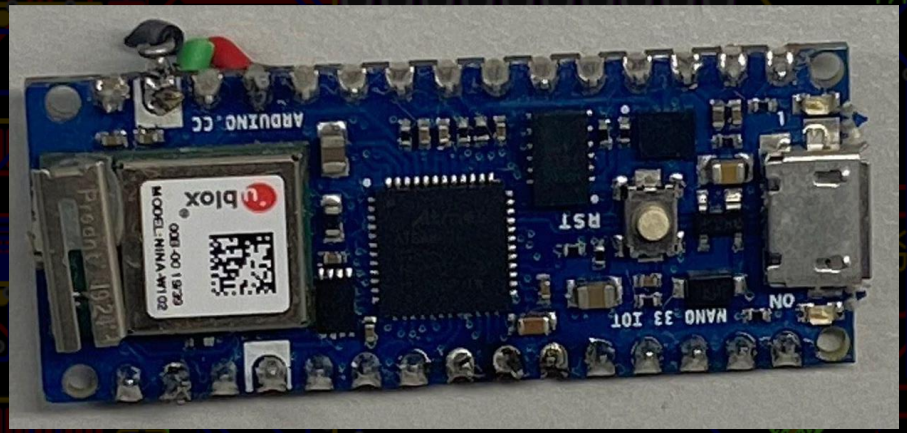
- Dedicated serial line for hosting USB
- **SAMD21 chipset**

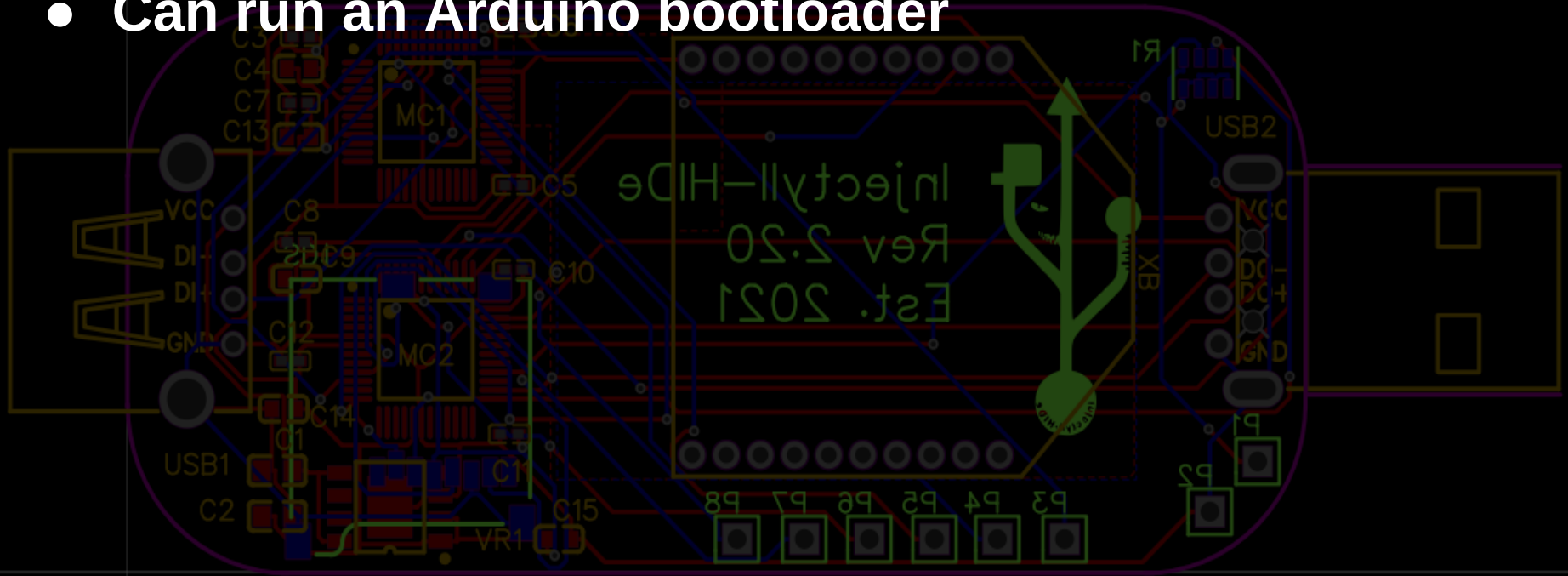


Arduino Nano 33 IoT



Arduino Nano 33 IoT

- **Can run an Arduino bootloader**



Arduino Nano 33 IoT

- Can run an Arduino bootloader
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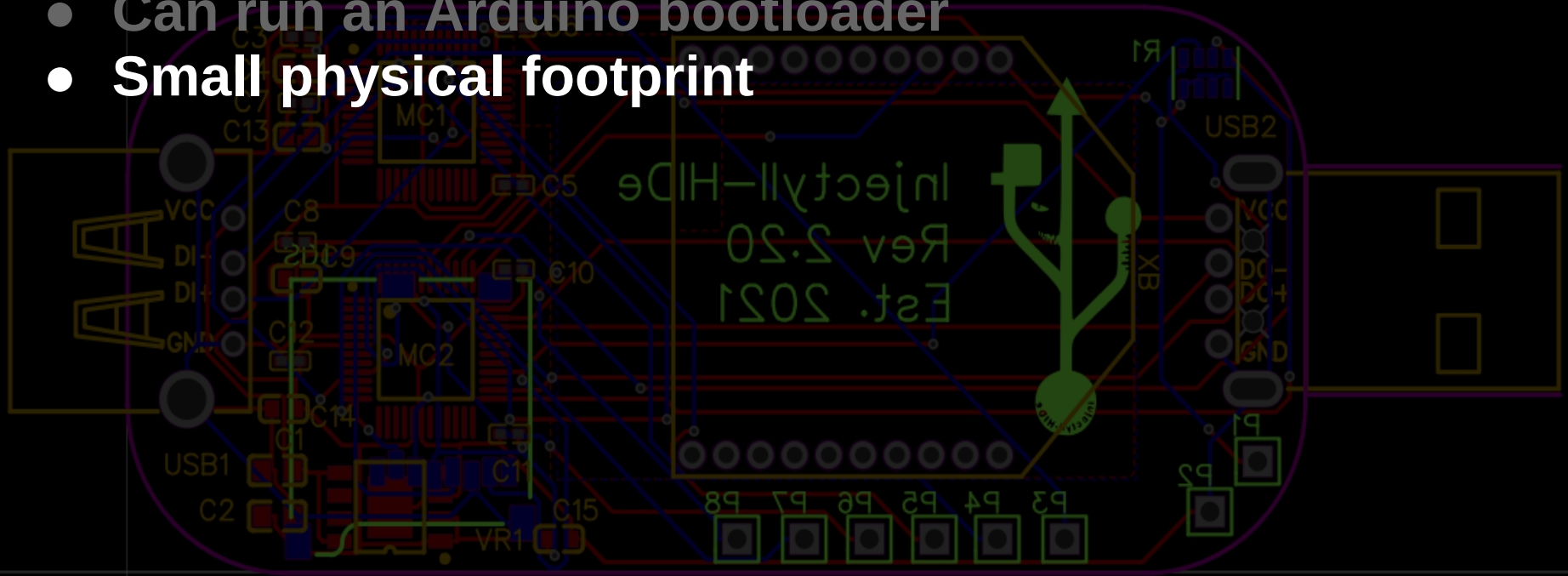
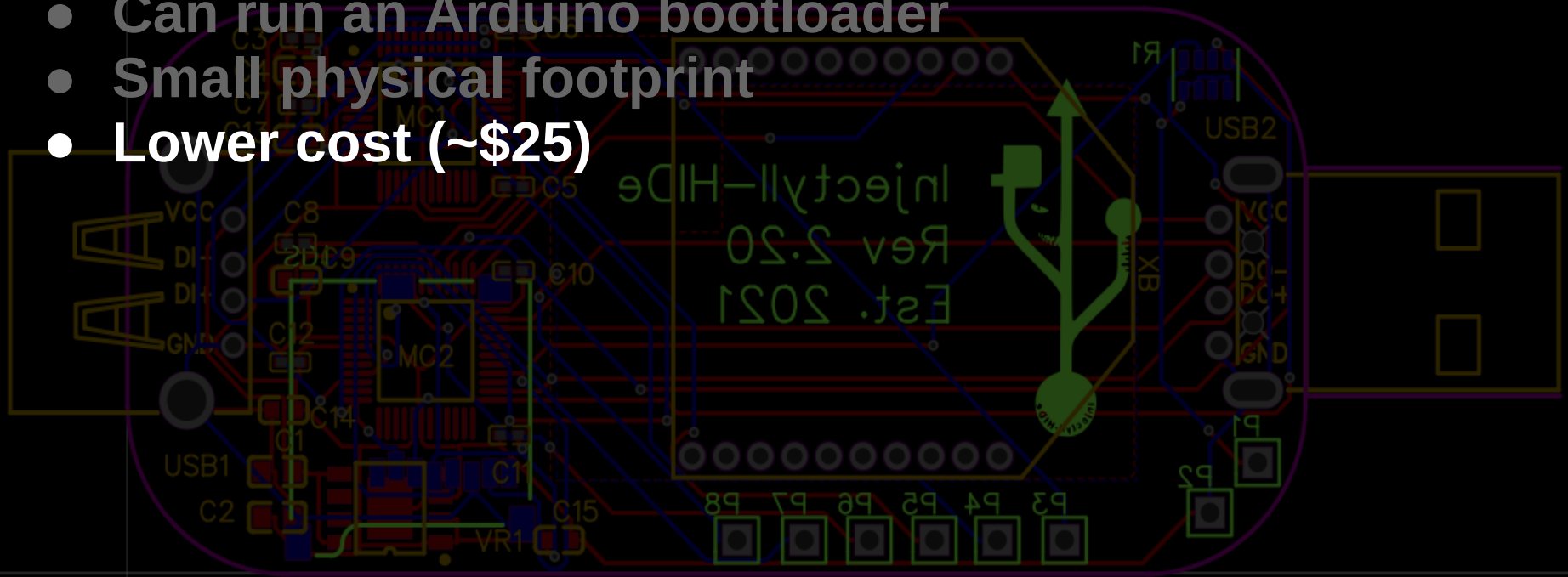


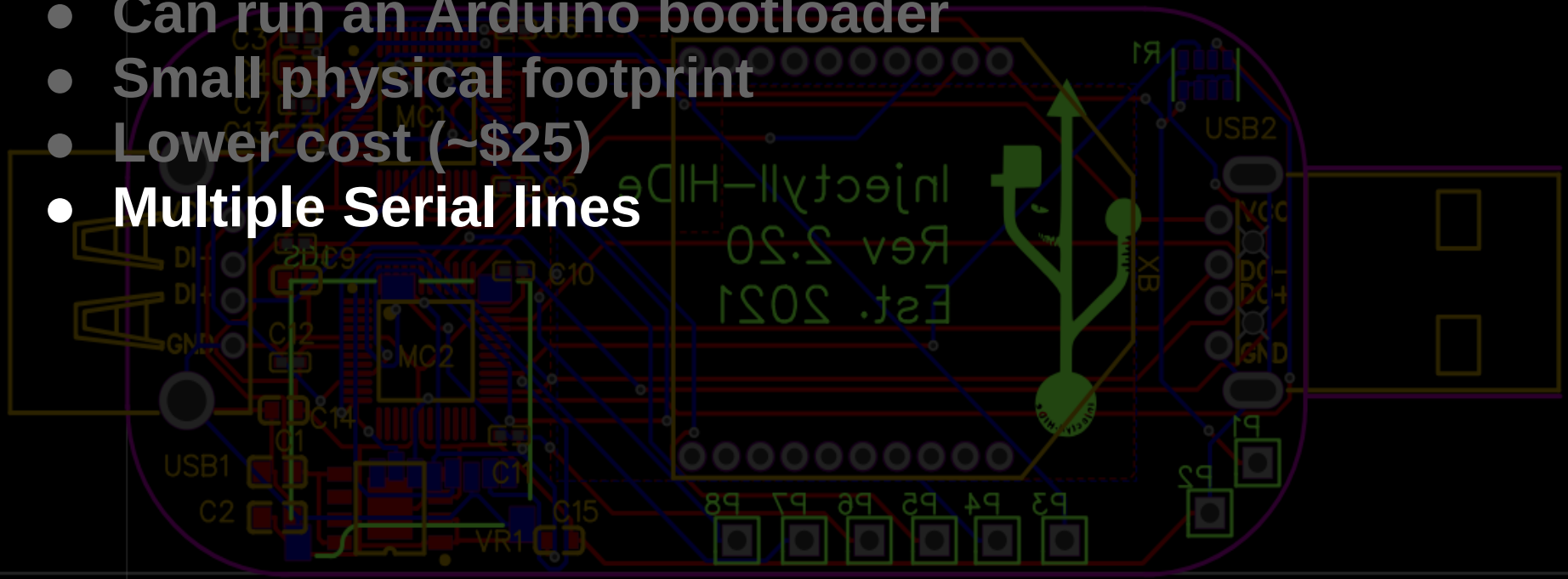
Arduino Nano 33 IoT

- Can run an Arduino bootloader
- Small physical footprint
- **Lower cost (~$25)**



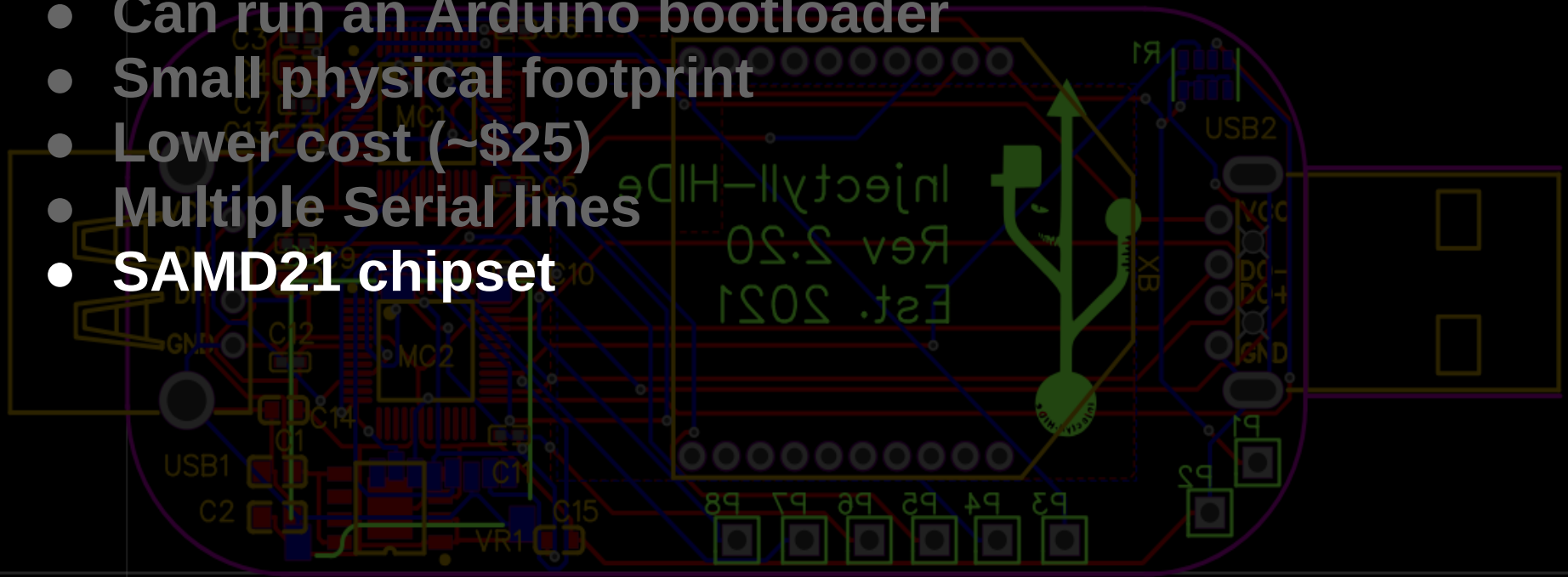
Arduino Nano 33 IoT

- Can run an Arduino bootloader
- Small physical footprint
- Lower cost (~$25)
- **Multiple Serial lines**



Arduino Nano 33 IoT

- Can run an Arduino bootloader
- Small physical footprint
- Lower cost (~$25)
- Multiple Serial lines
- **SAMD21 chipset**



Arduino Nano 33 IoT

- Can run an Arduino bootloader
- Small physical footprint
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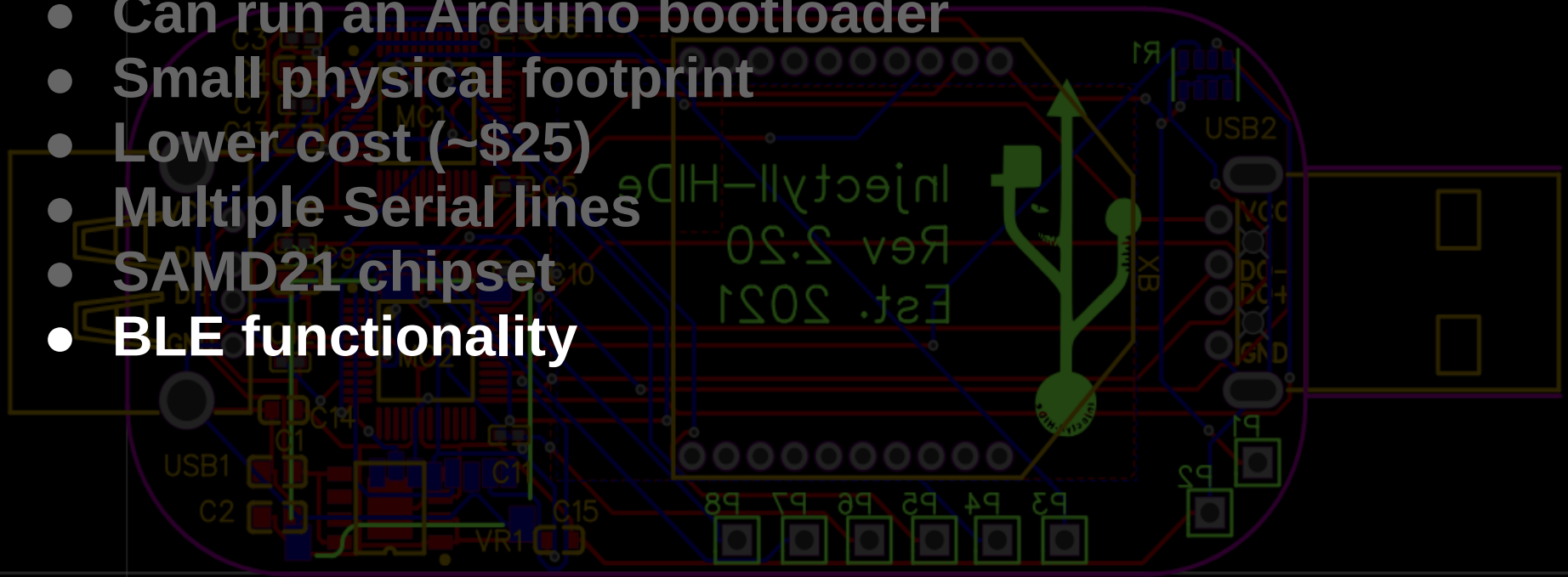
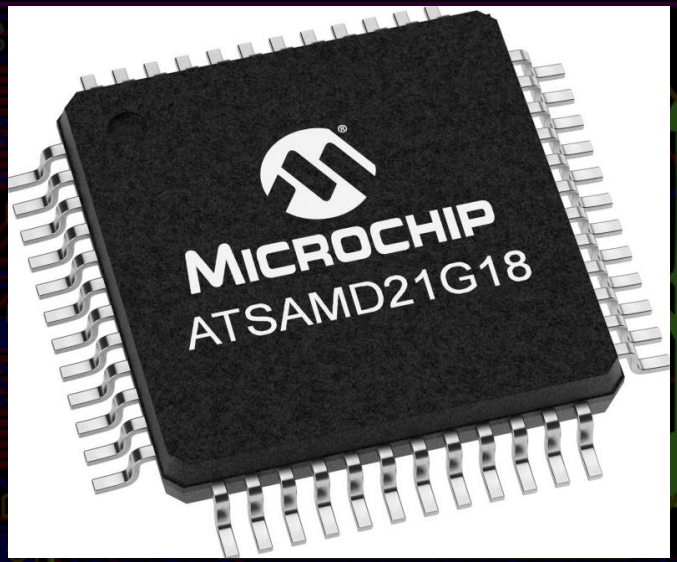
- Multiple Serial lines
- SAMD21 chipset
- **BLE functionality**

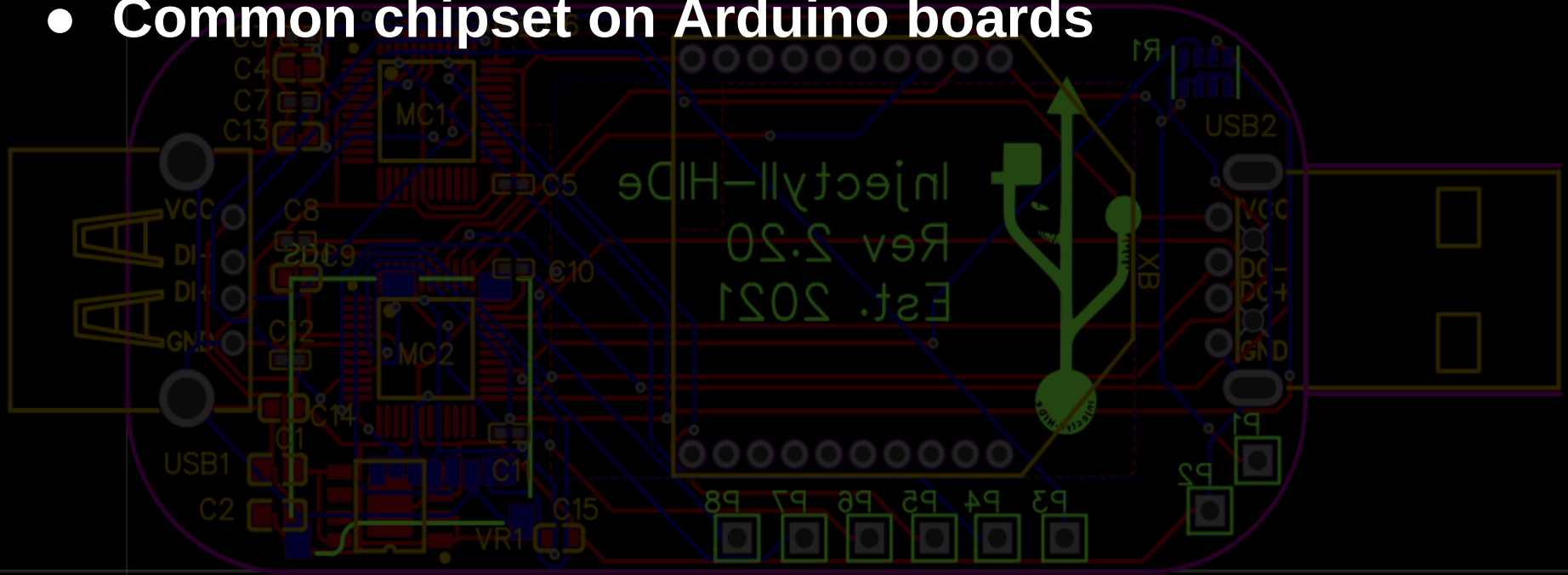


Why SAMD21?



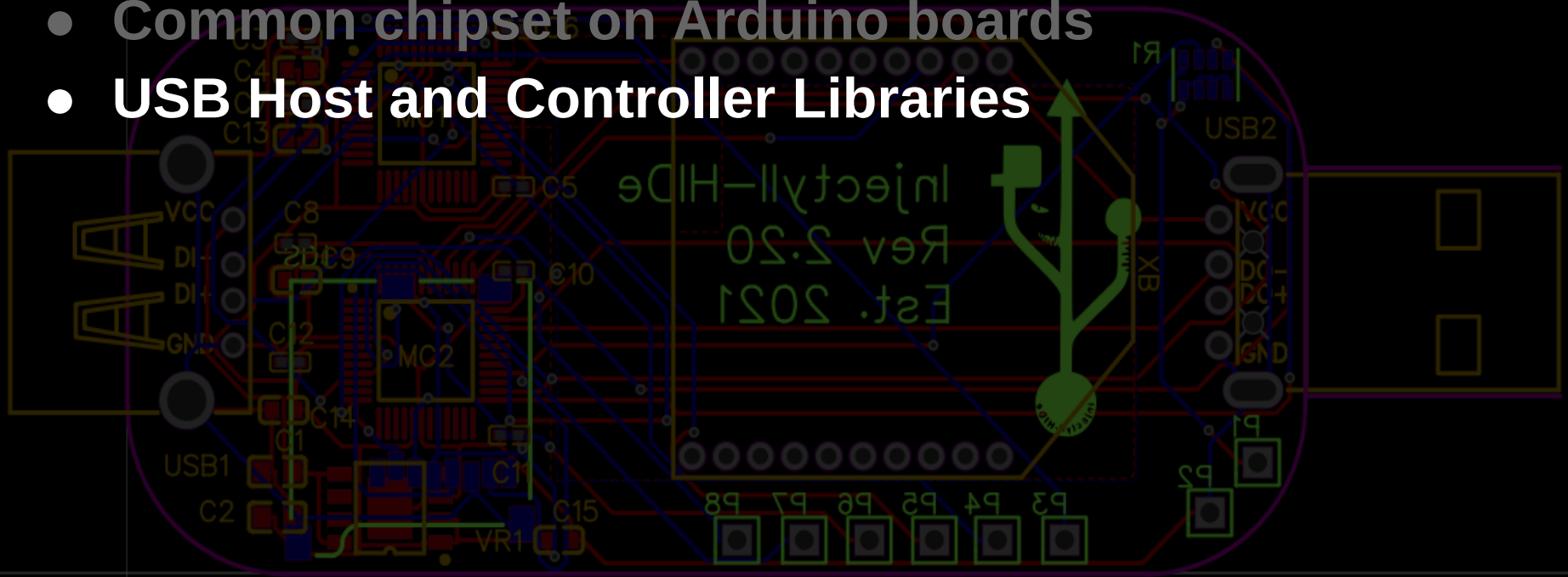
Why SAMD21?

- **Common chipset on Arduino boards**



Why SAMD21?

- Common chipset on Arduino boards
- **USB Host and Controller Libraries**



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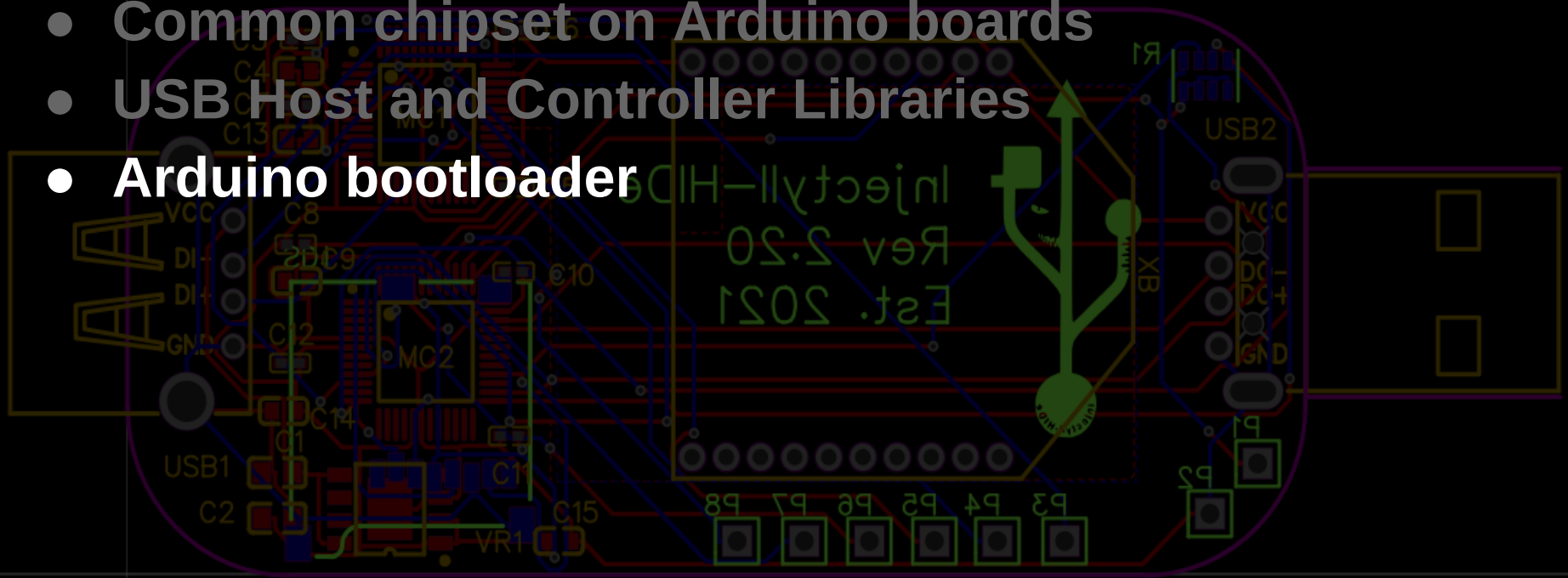
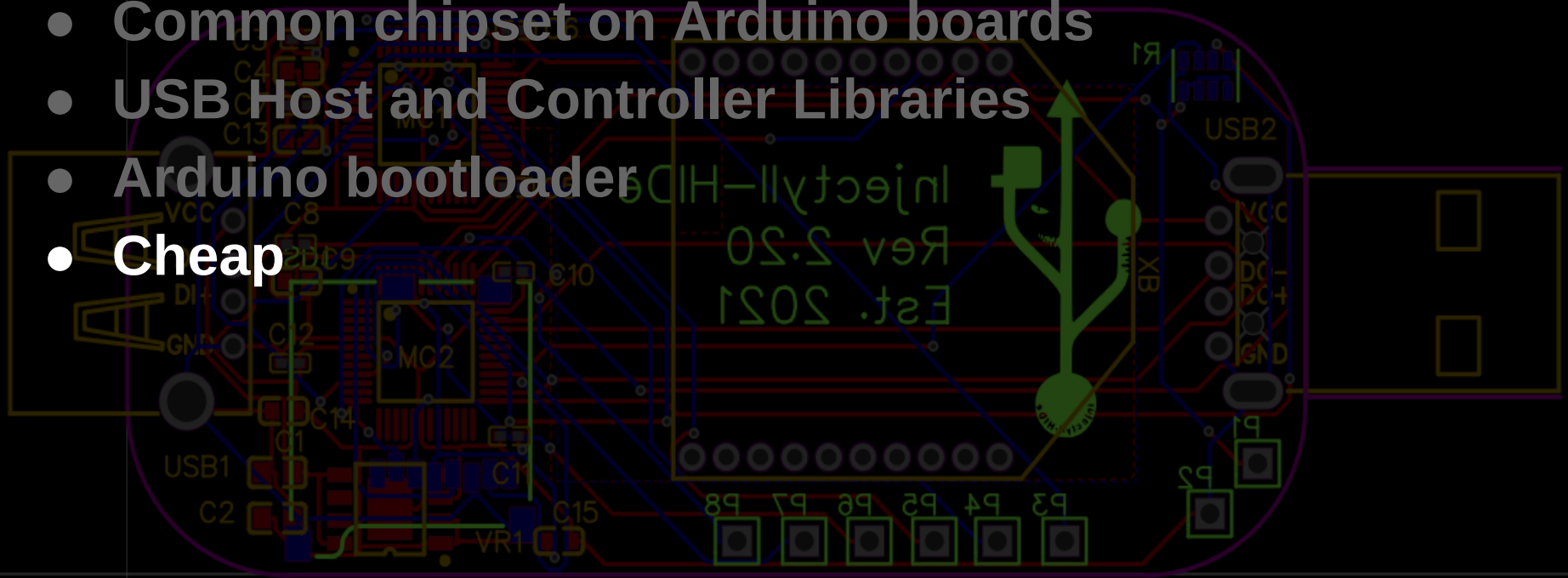


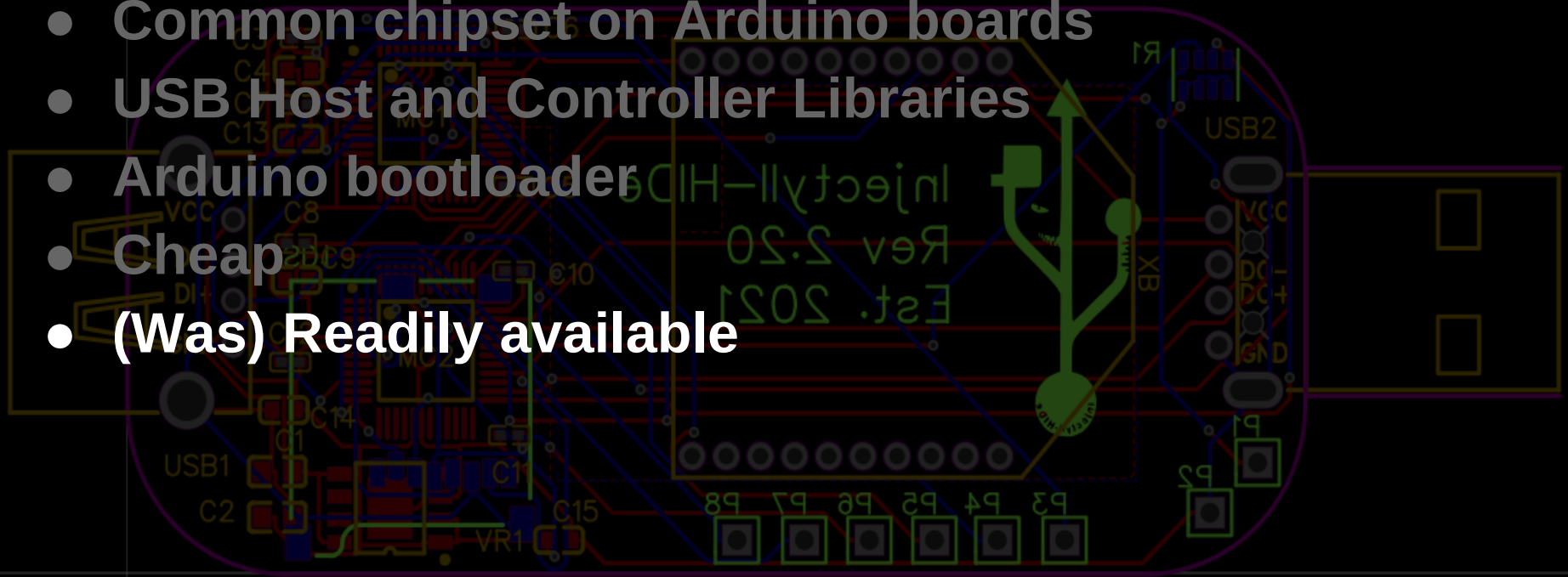
Why SAMD21?

- Common chipset on Arduino boards
- USB Host and Controller Libraries
- Arduino bootloader
- **Cheap**



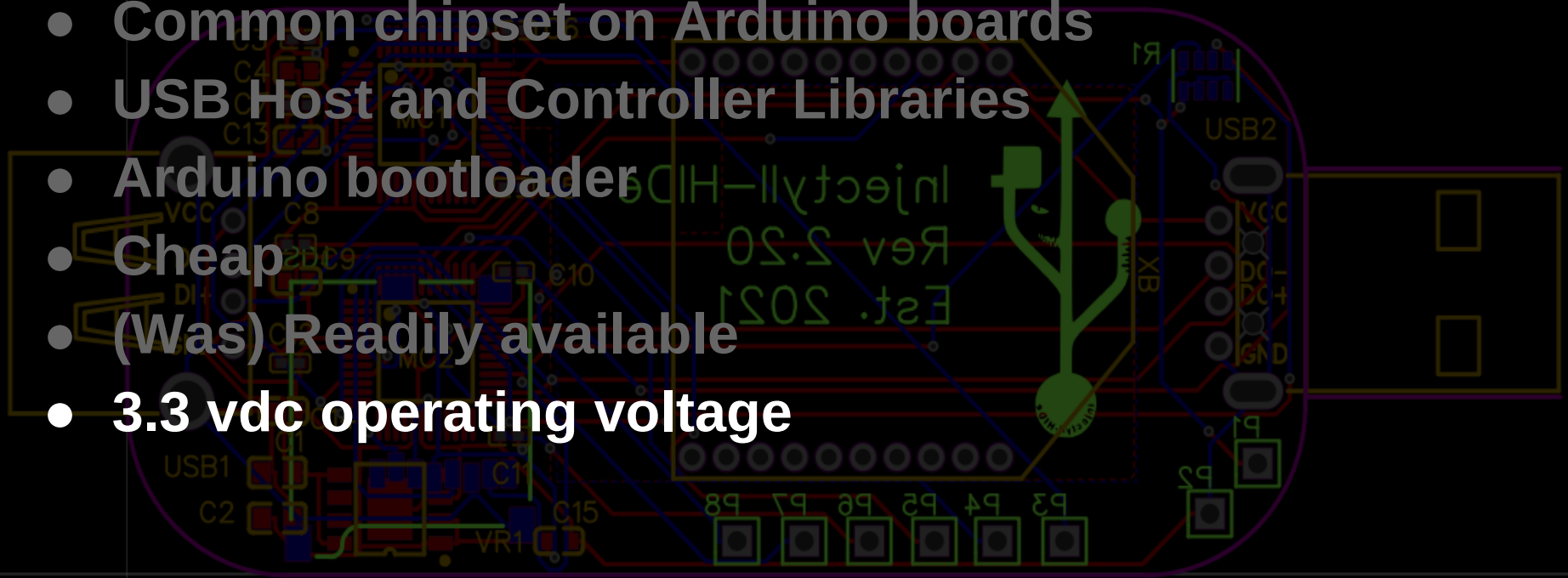
Why SAMD21?

- Common chipset on Arduino boards
- USB Host and Controller Libraries
- Arduino bootloader
- Cheap
- **(Was) Readily available**

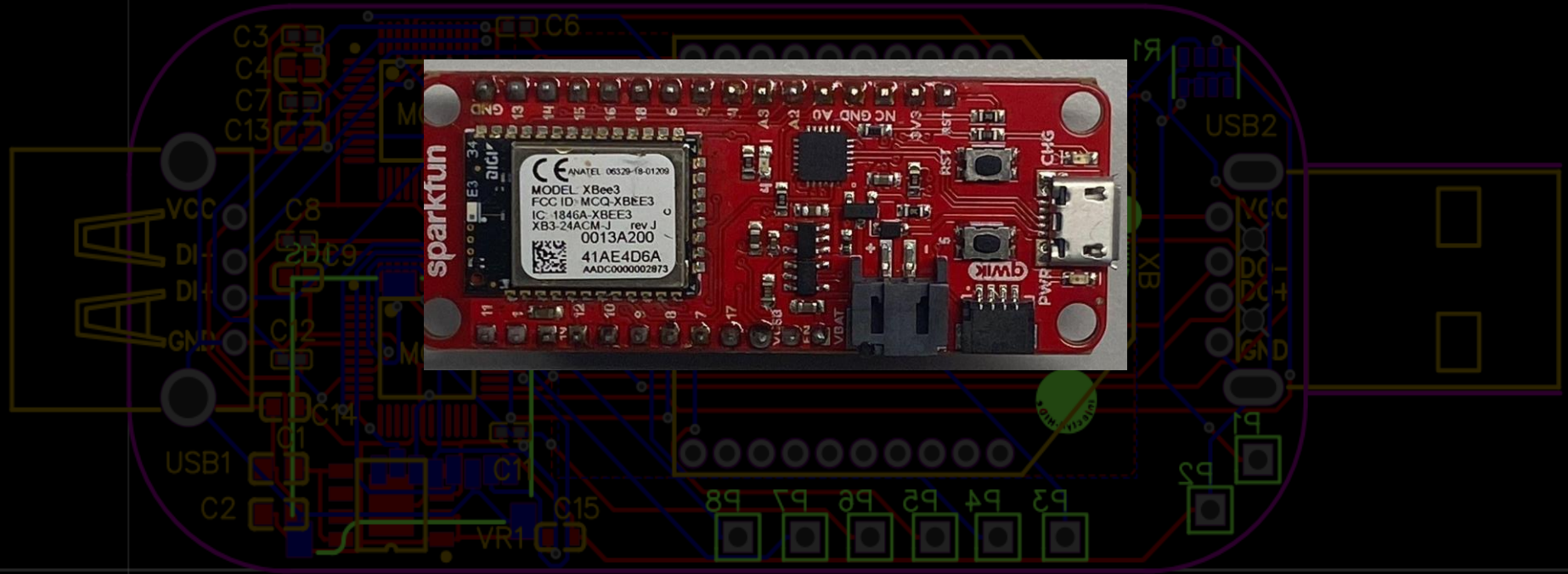


Why SAMD21?

- Common chipset on Arduino boards
- USB Host and Controller Libraries
- Arduino bootloader
- Cheap
- (Was) Readily available
- **3.3 vdc operating voltage**

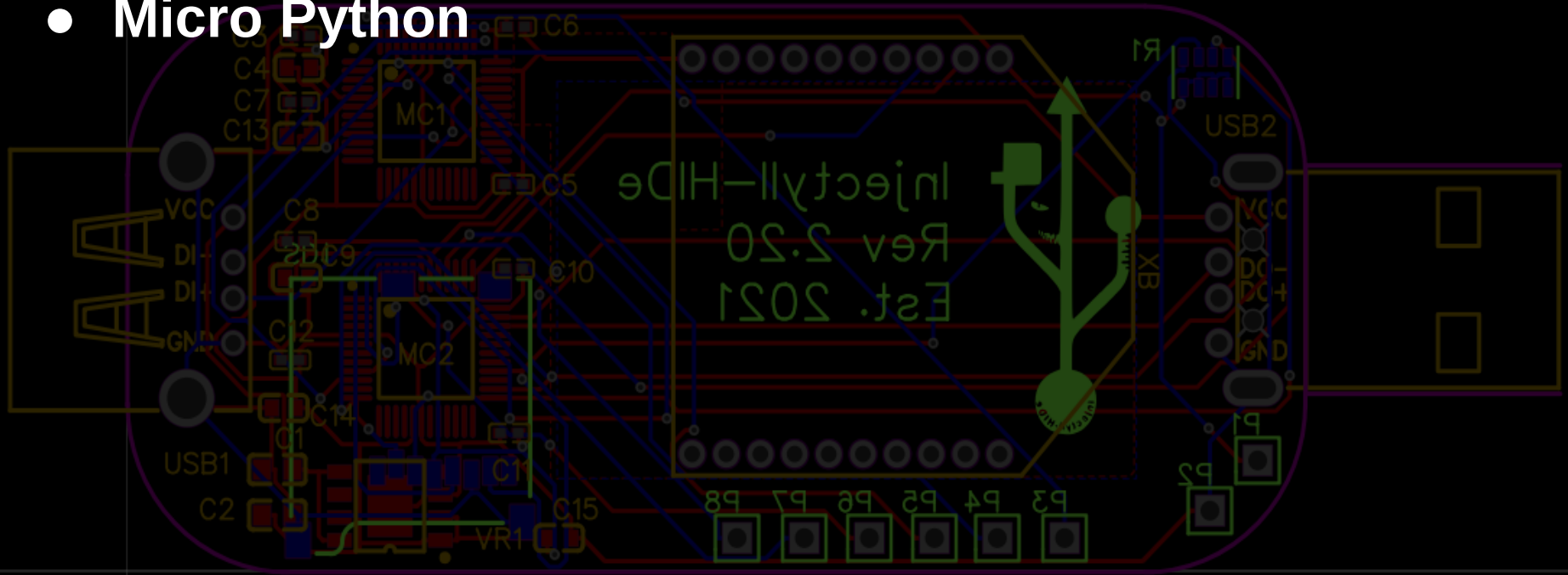


SparkFun XBee3 Thing Plus Board



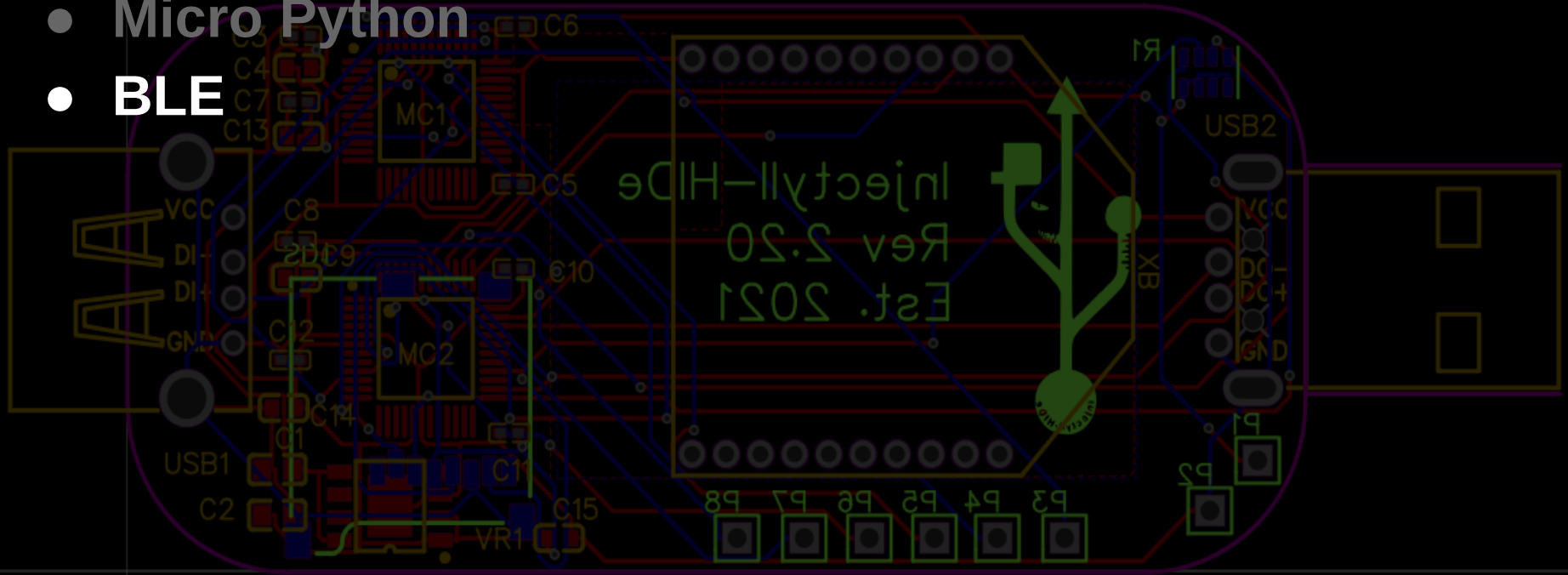
SparkFun XBee3 Thing Plus Board

- **Micro Python**



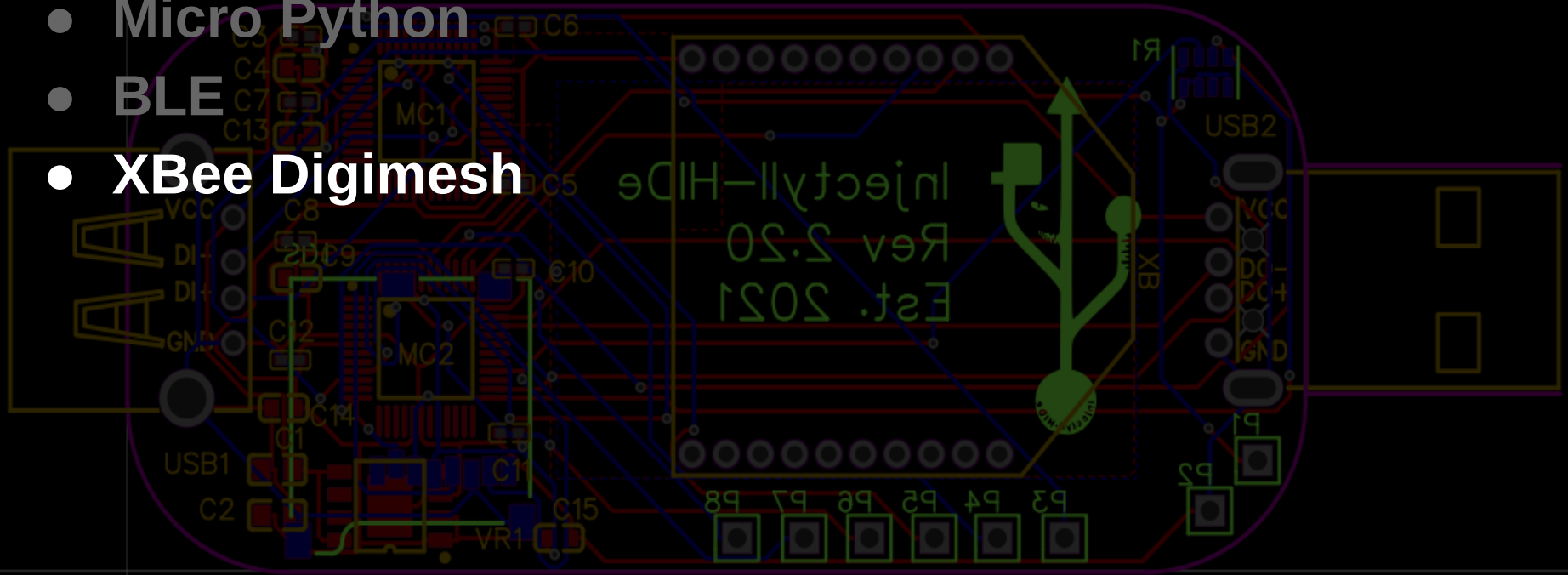
SparkFun XBee3 Thing Plus Board

- Micro Python
- **BLE**



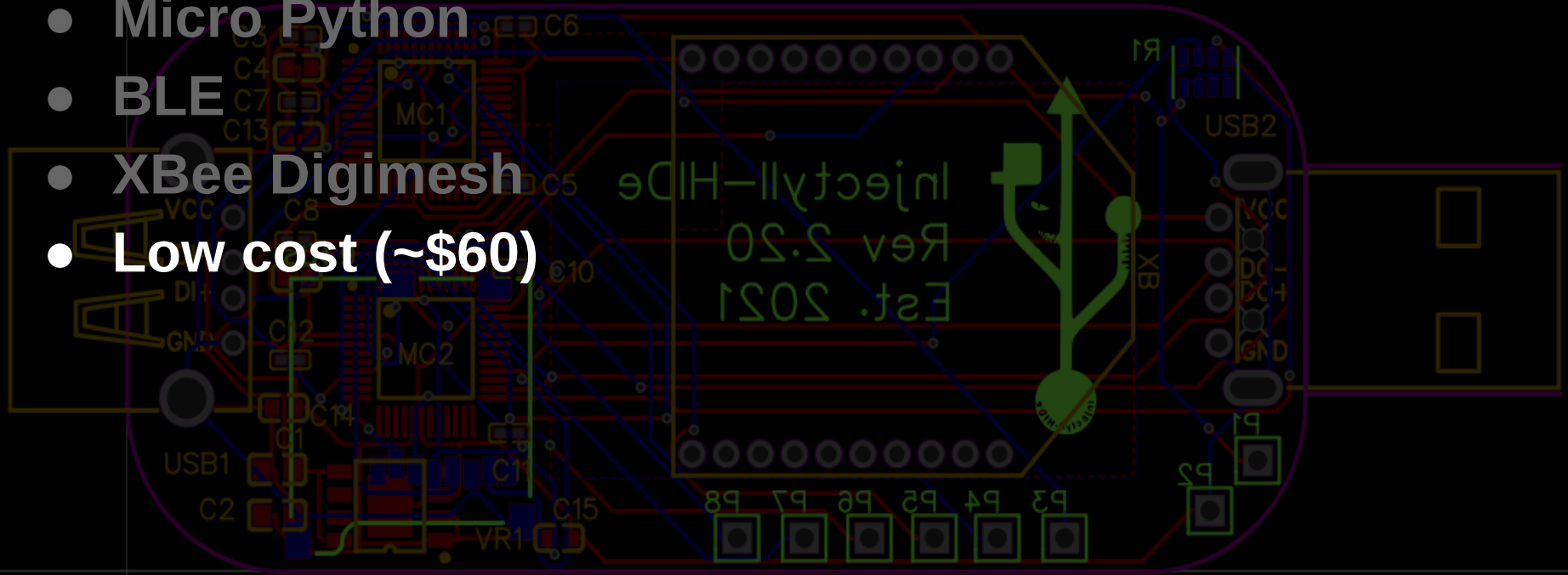
SparkFun XBee3 Thing Plus Board

- Micro Python
- BLE
- **XBee Digimesh**

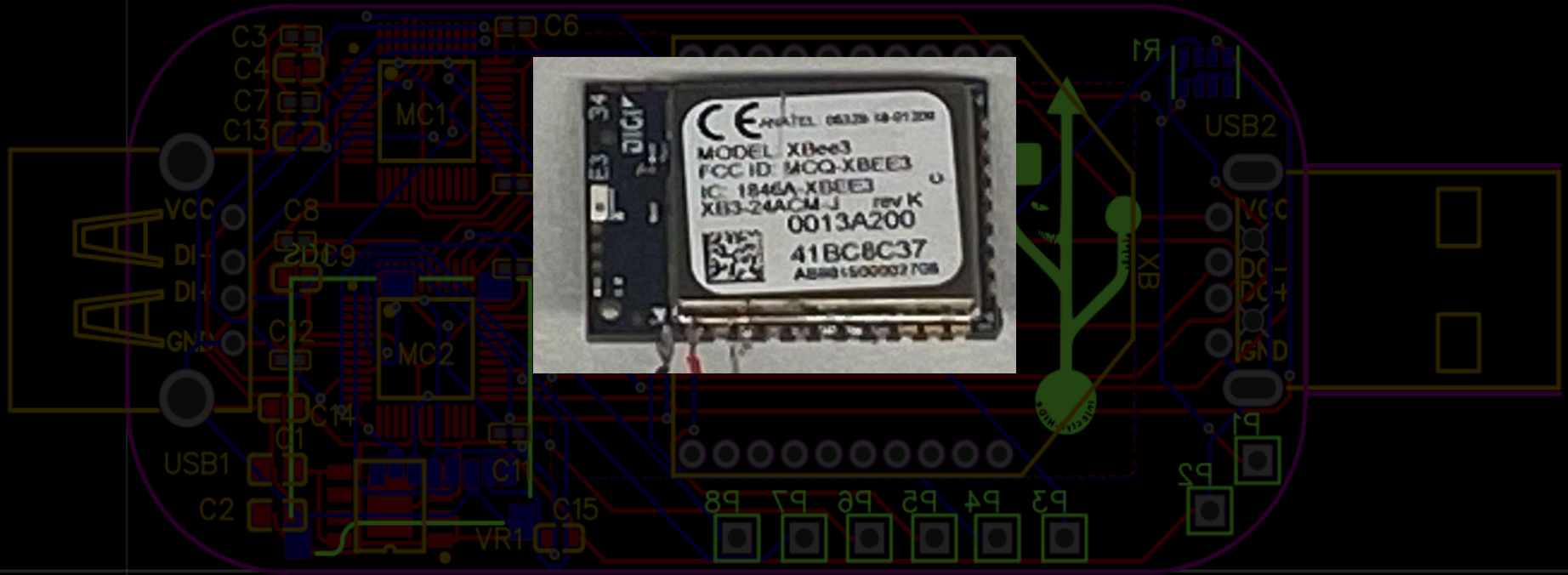


SparkFun XBee3 Thing Plus Board

- Micro Python
- BLE
- XBee Digimesh
- **Low cost (~$60)**

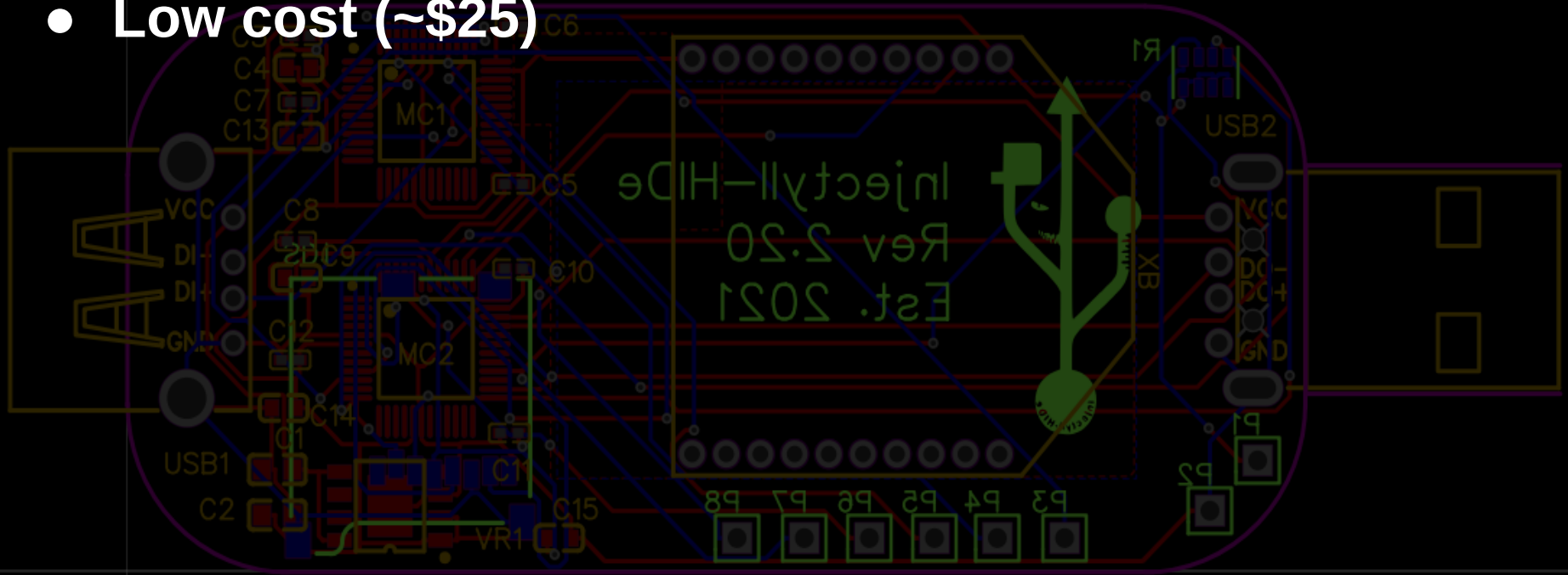


Digi XBee DigiMesh Radio



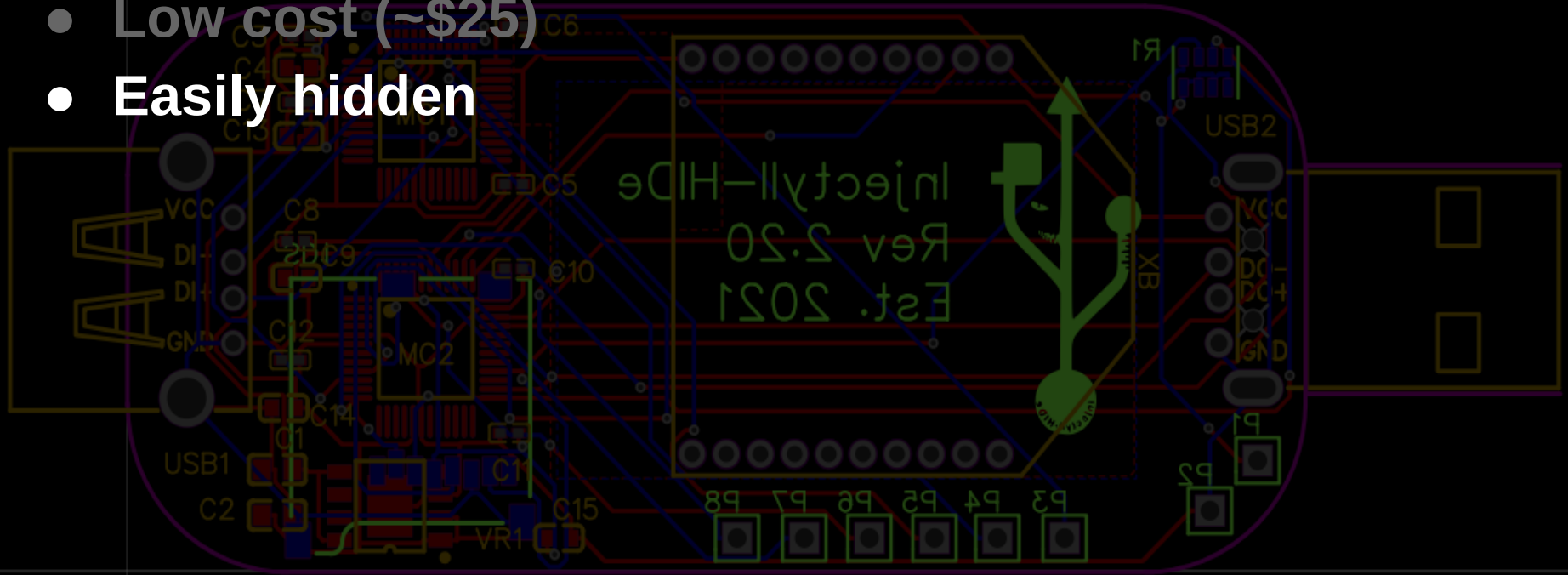
Digi XBee DigiMesh Radio

- **Low cost (~$25)**



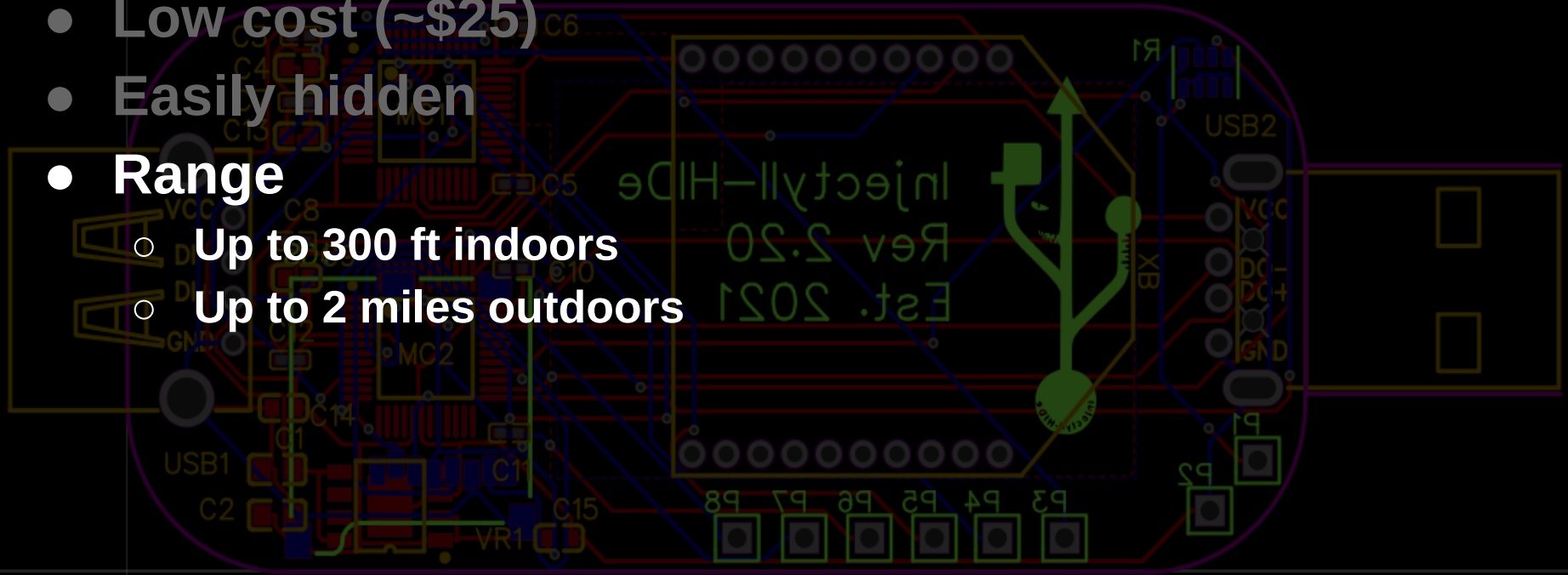
Digi XBee DigiMesh Radio

- Low cost (~$25)
- **Easily hidden**



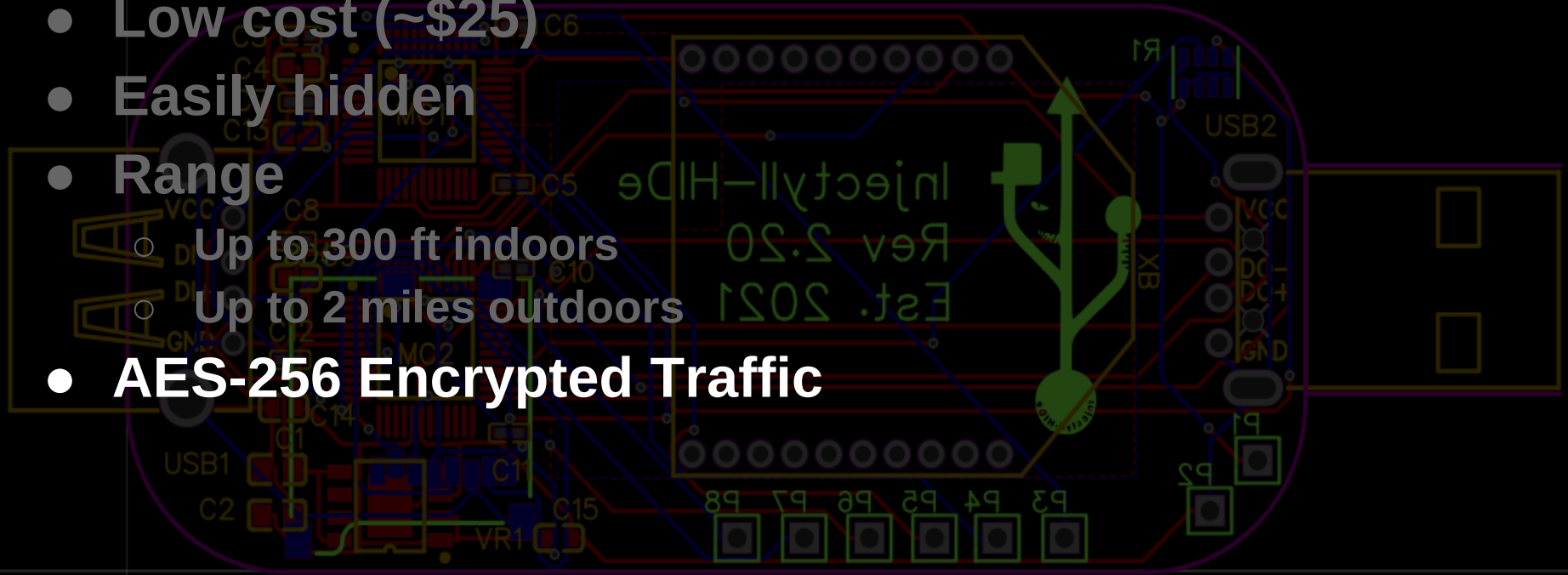
Digi XBee DigiMesh Radio

- Low cost (~$25)
- Easily hidden
- **Range**
  - **Up to 300 ft indoors**
  - **Up to 2 miles outdoors**



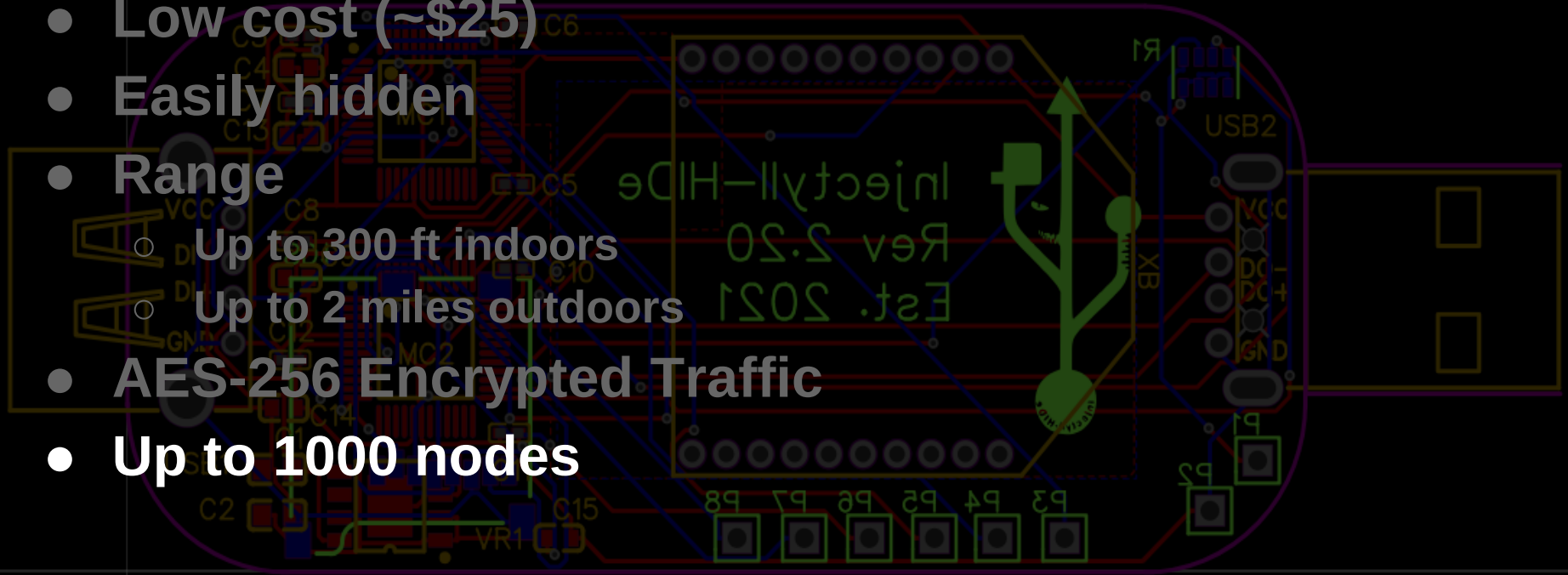
Digi XBee DigiMesh Radio

- Low cost (~$25)
- Easily hidden
- Range
  - Up to 300 ft indoors
  - Up to 2 miles outdoors
- **AES-256 Encrypted Traffic**

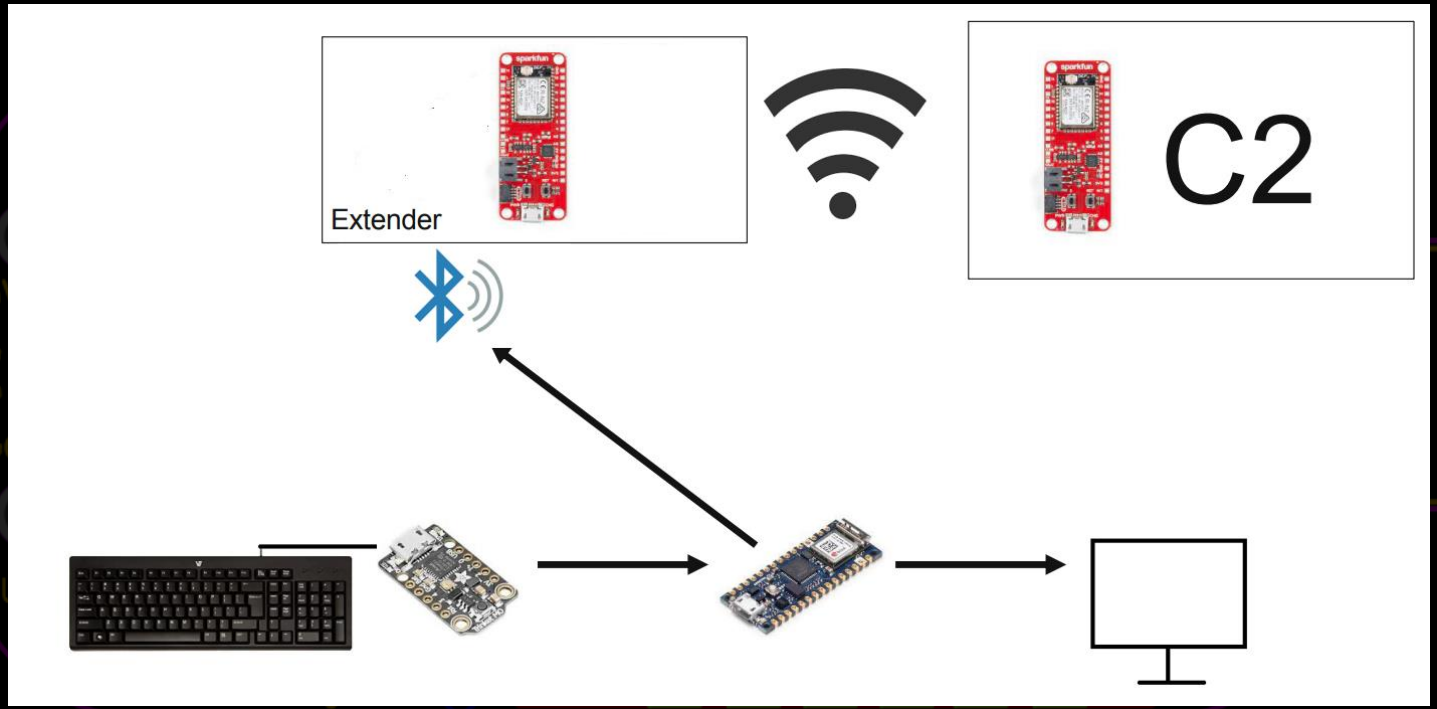


Digi XBee DigiMesh Radio

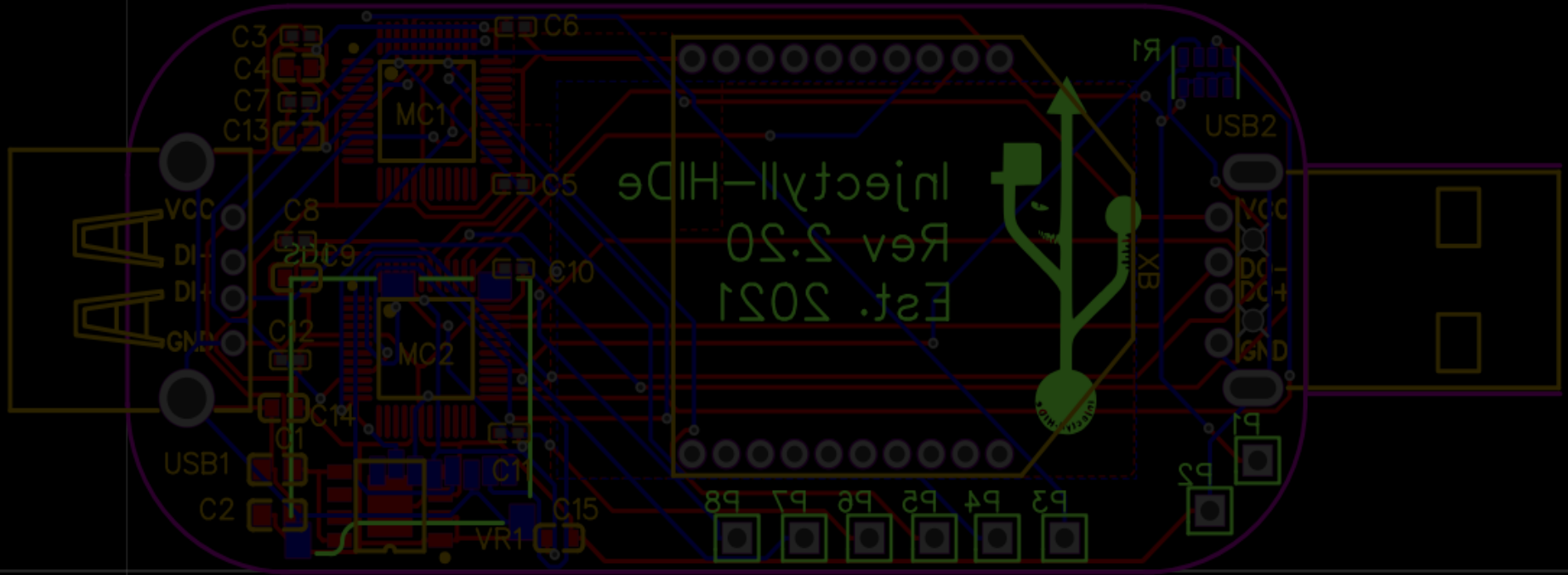
- Low cost (~$25)
- Easily hidden
- Range
  - Up to 300 ft indoors
  - Up to 2 miles outdoors
- AES-256 Encrypted Traffic
- **Up to 1000 nodes**



Proof of Concept Layout



Proof of Concept Lessons Learned



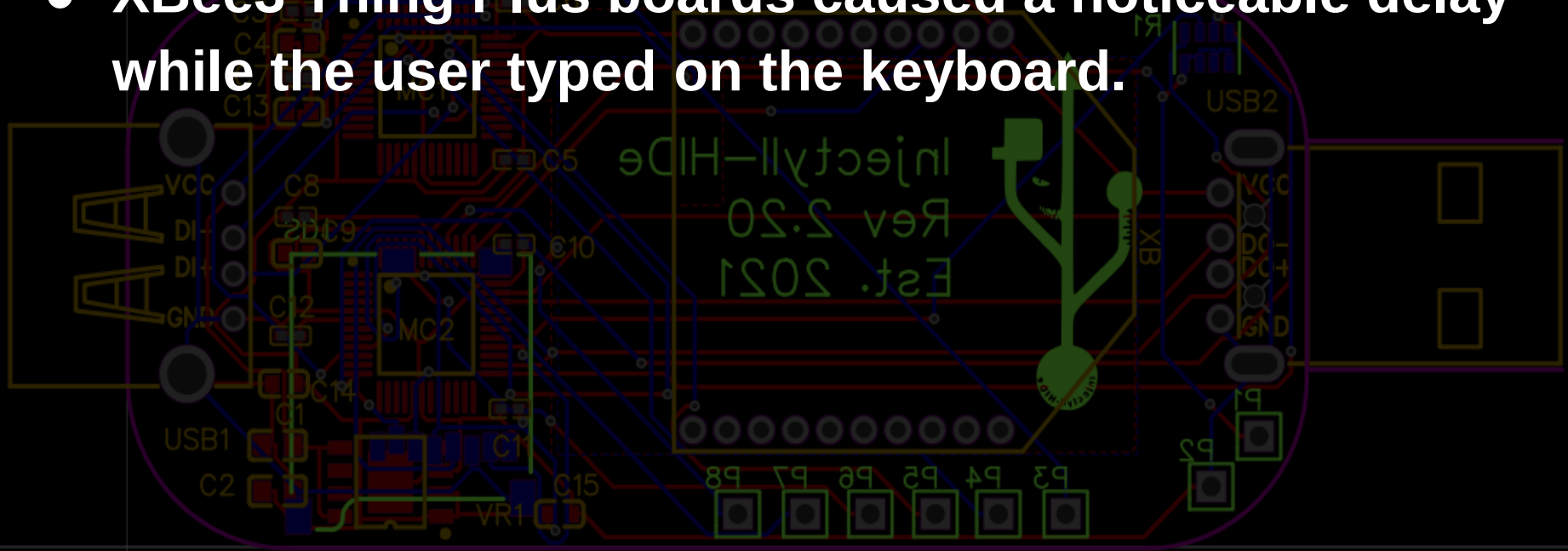
@c4m0ufl4g3

@Injectyll_HIDe

@allTheJurm

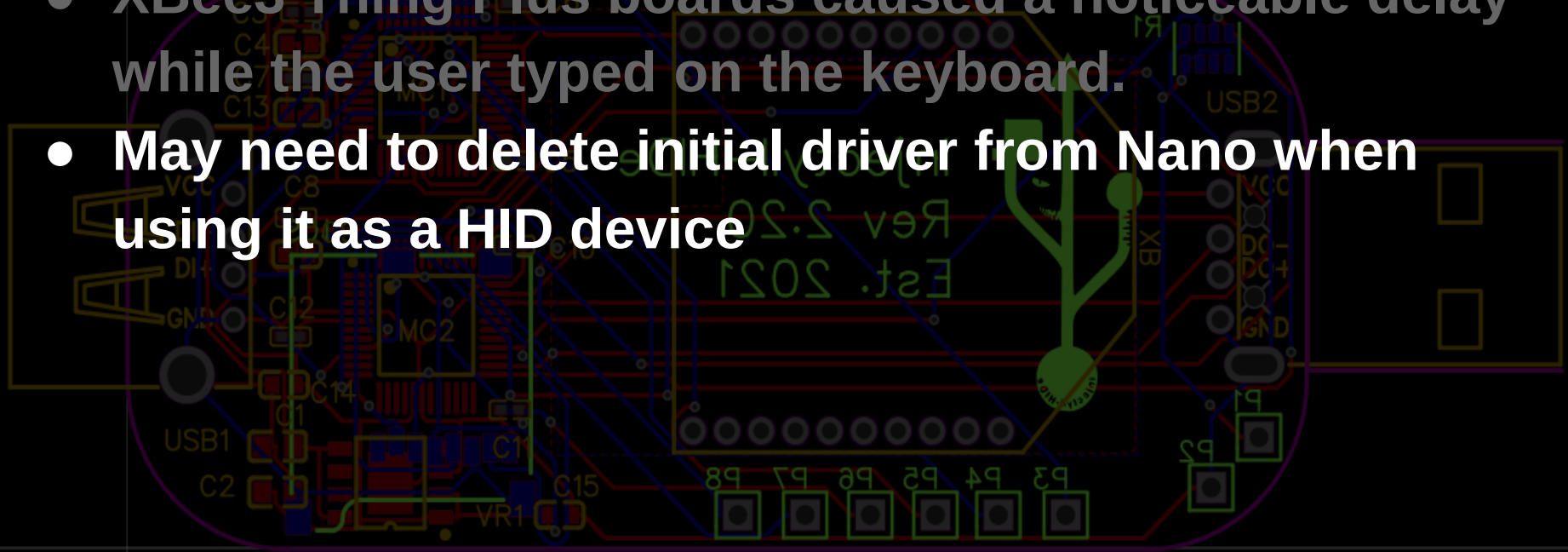
Proof of Concept Lessons Learned

- **XBee3 Thing Plus boards caused a noticeable delay while the user typed on the keyboard.**



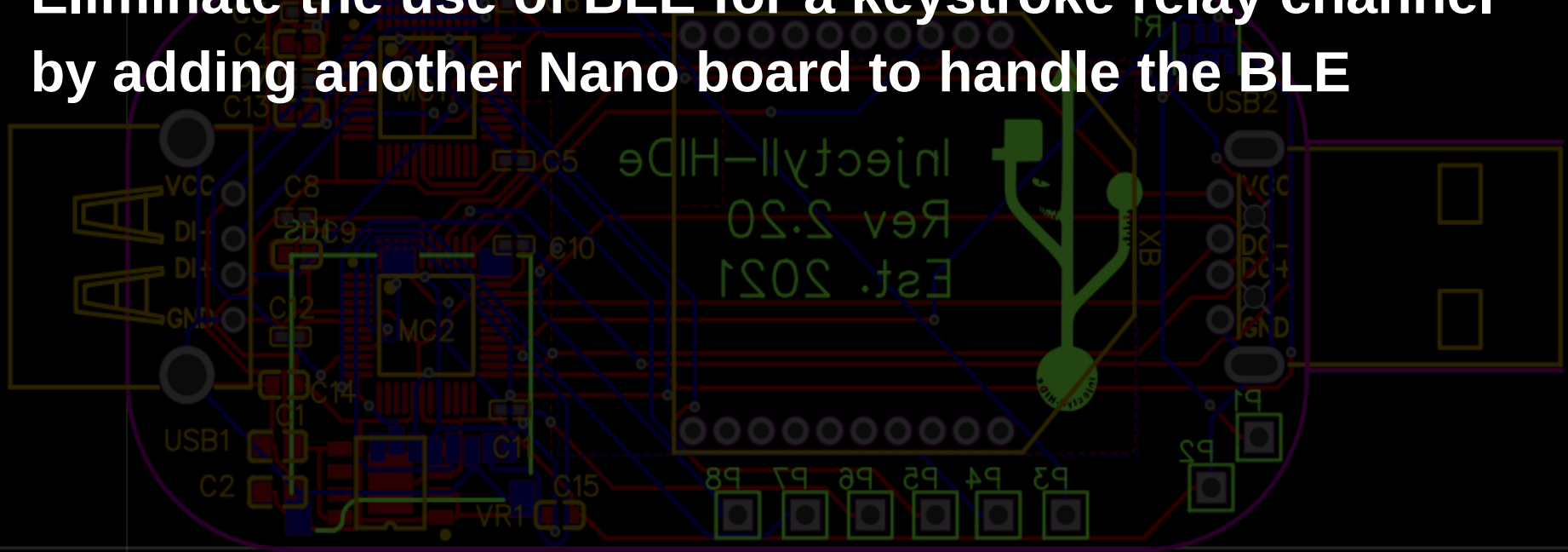
Proof of Concept Lessons Learned

- XBee3 Thing Plus boards caused a noticeable delay while the user typed on the keyboard.
- **May need to delete initial driver from Nano when using it as a HID device**

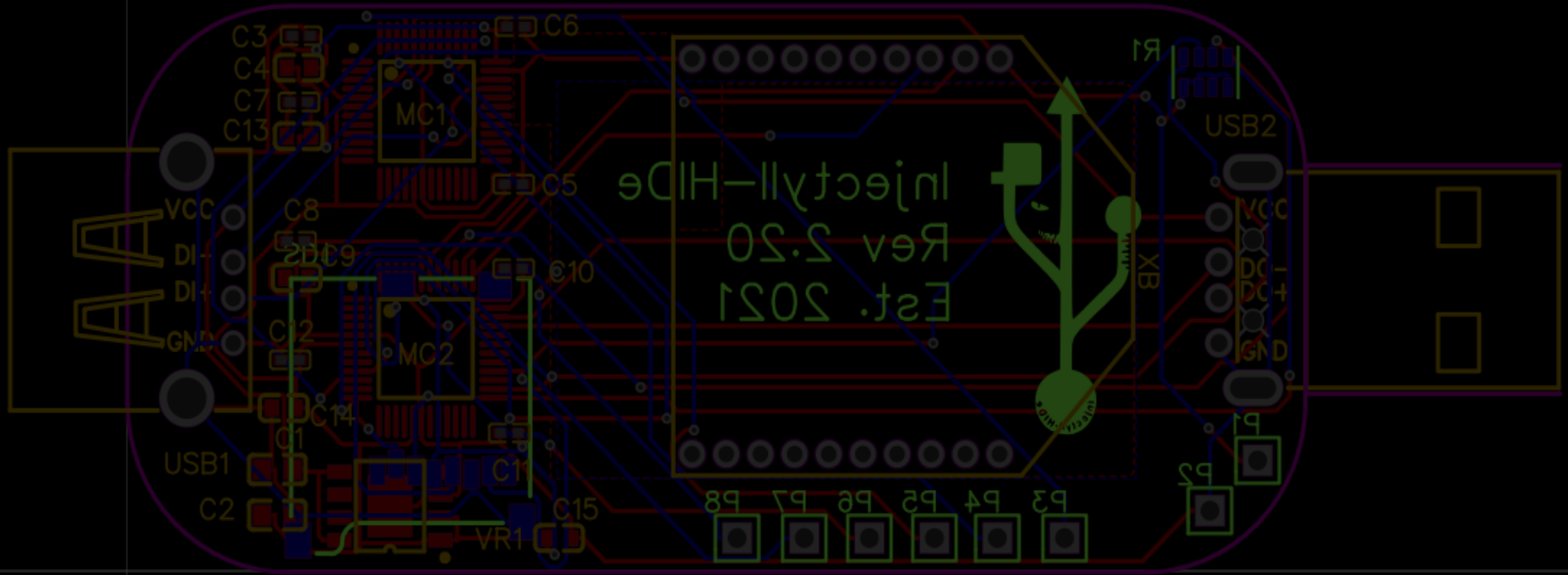


Proof of Concept Conclusion

Eliminate the use of BLE for a keystroke relay channel by adding another Nano board to handle the BLE

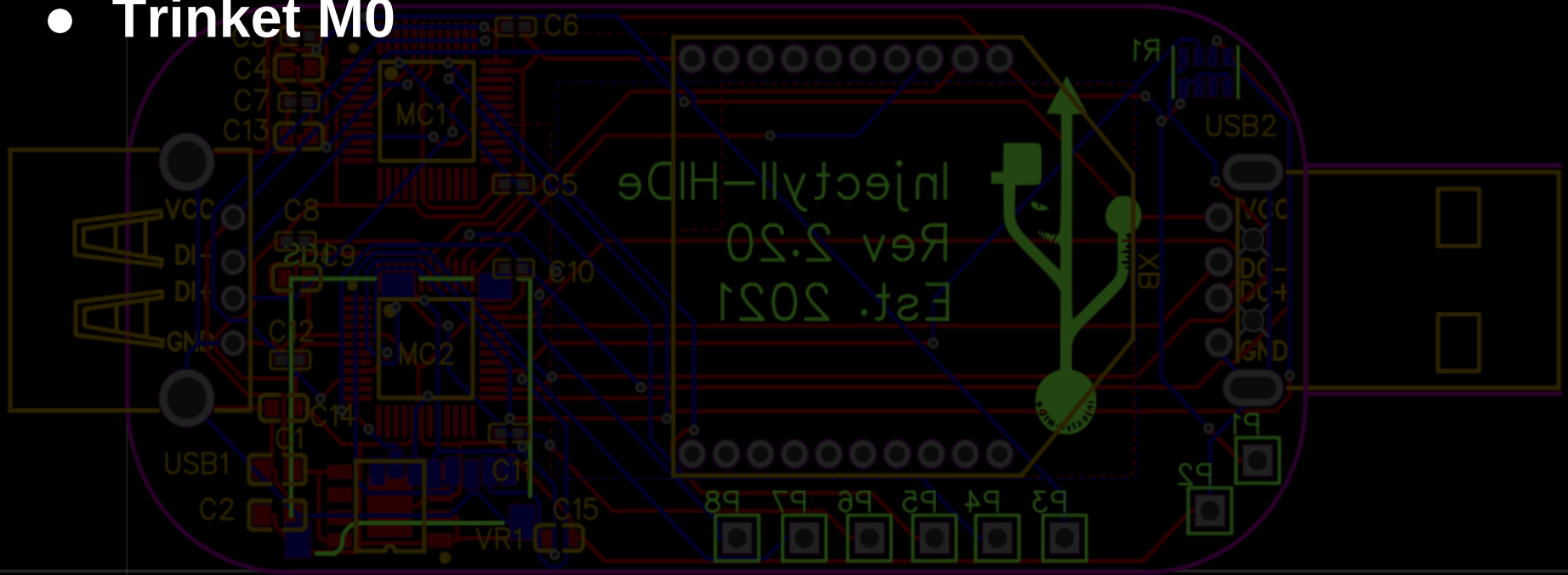


Prototype #1


C3
C4
C7
C13
C6
MC1
C5
C8
C9
C10
MC2
C12
C14
C1
C11
C15
VR1
USB1
C2
VCC
DI-
DI+
GND
Injectyll-HIDe
Rev 2.20
Est. 2021
R1
USB2
VCC
D-
D+
GND
P1
P2
P3
P4
P5
P6
P7
P8

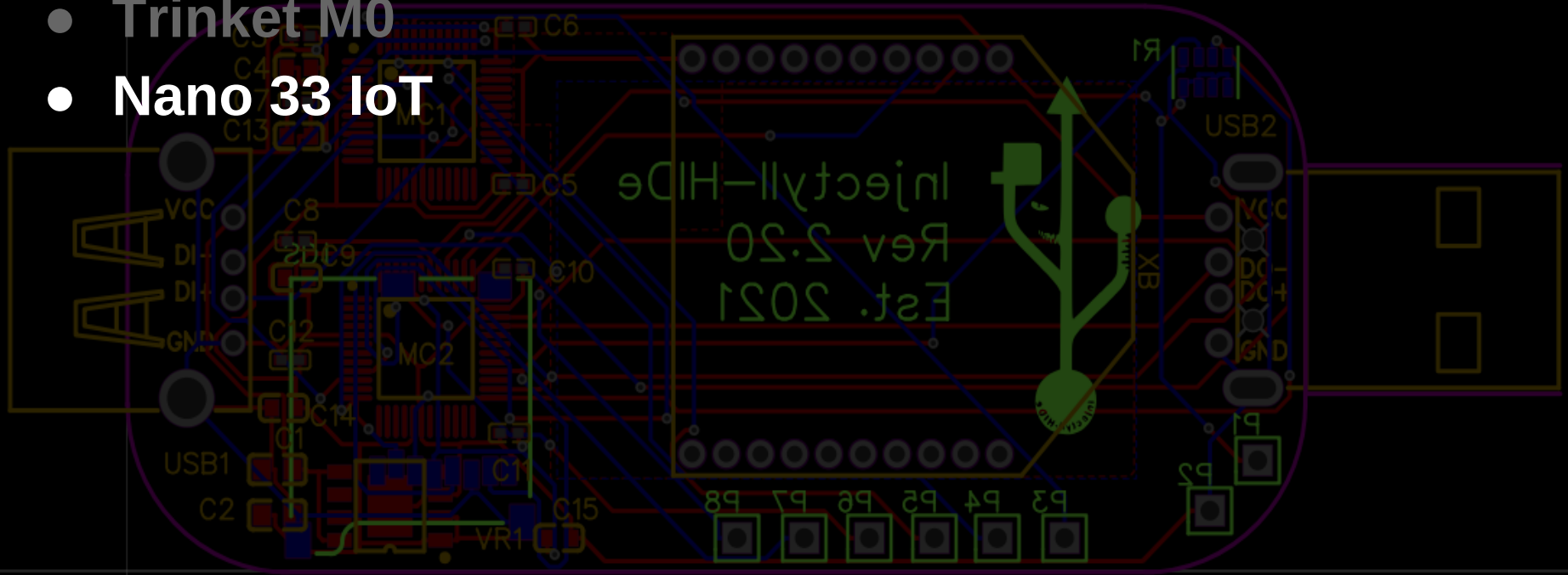
Prototype #1

- **Trinket M0**



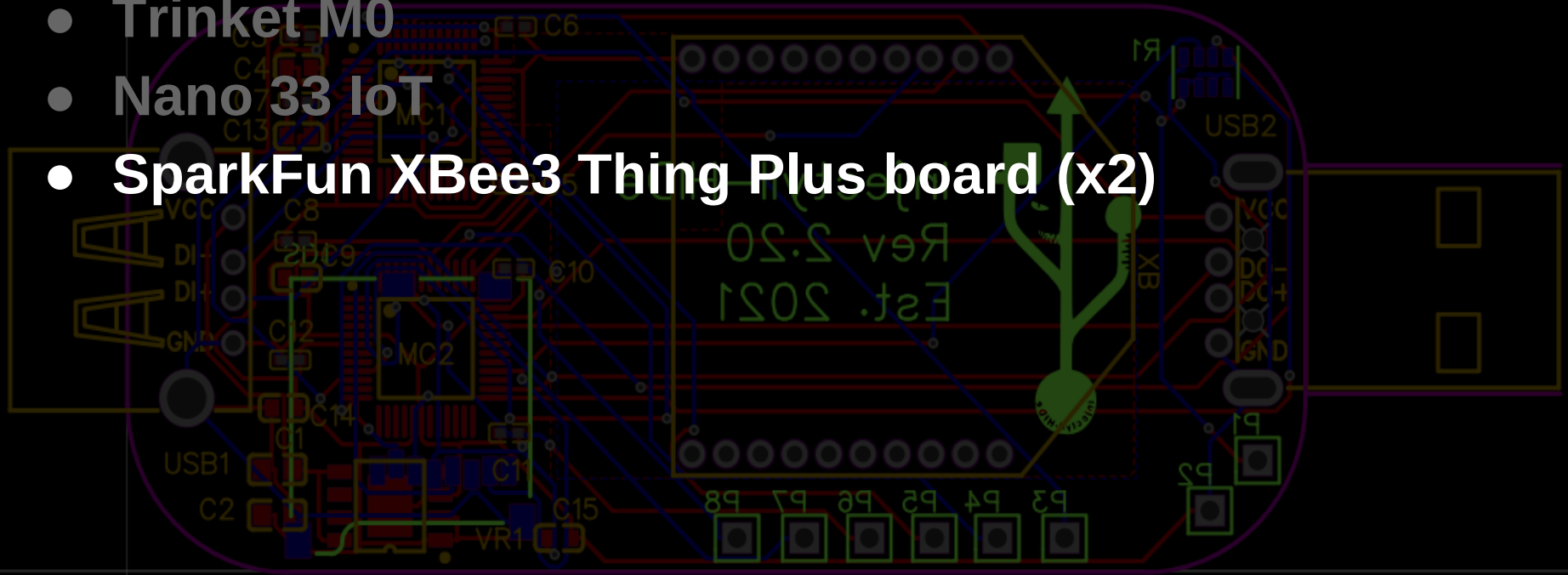
Prototype #1

- Trinket M0
- **Nano 33 IoT**

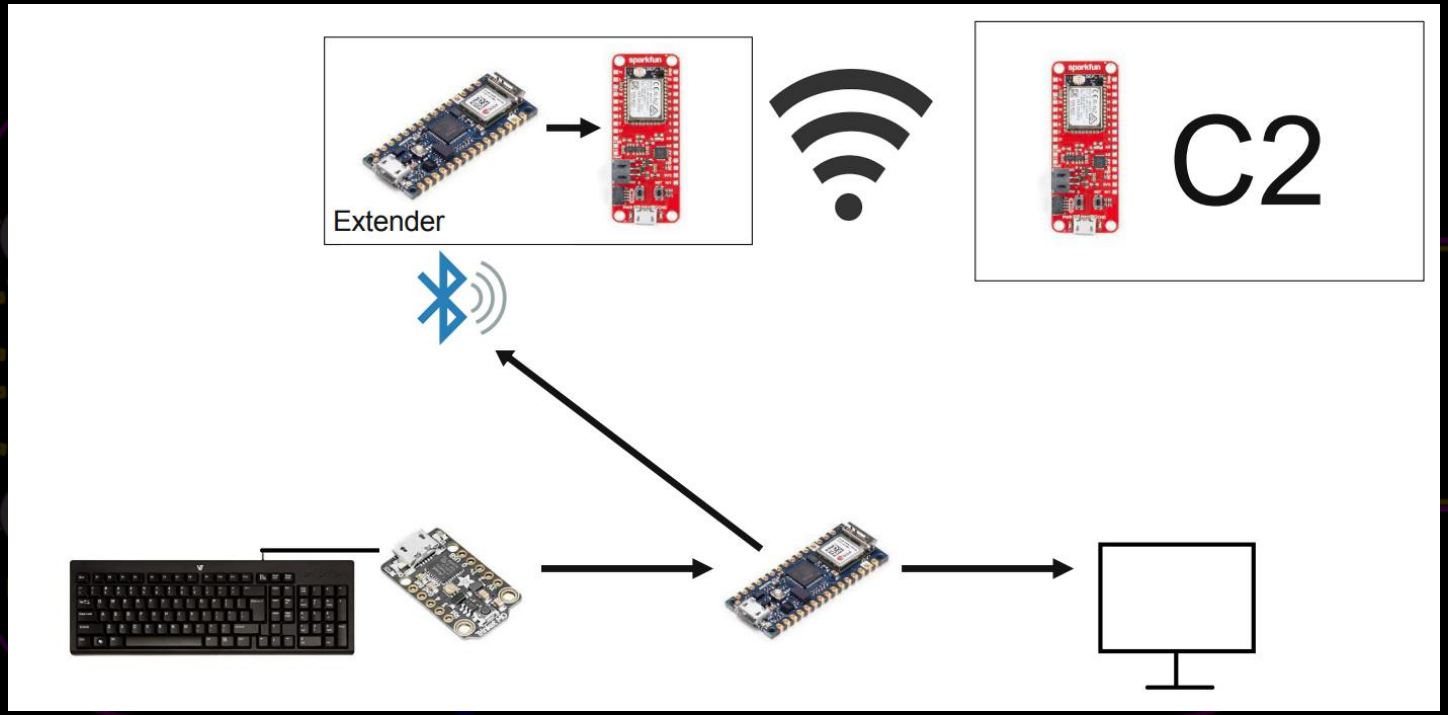


Prototype #1

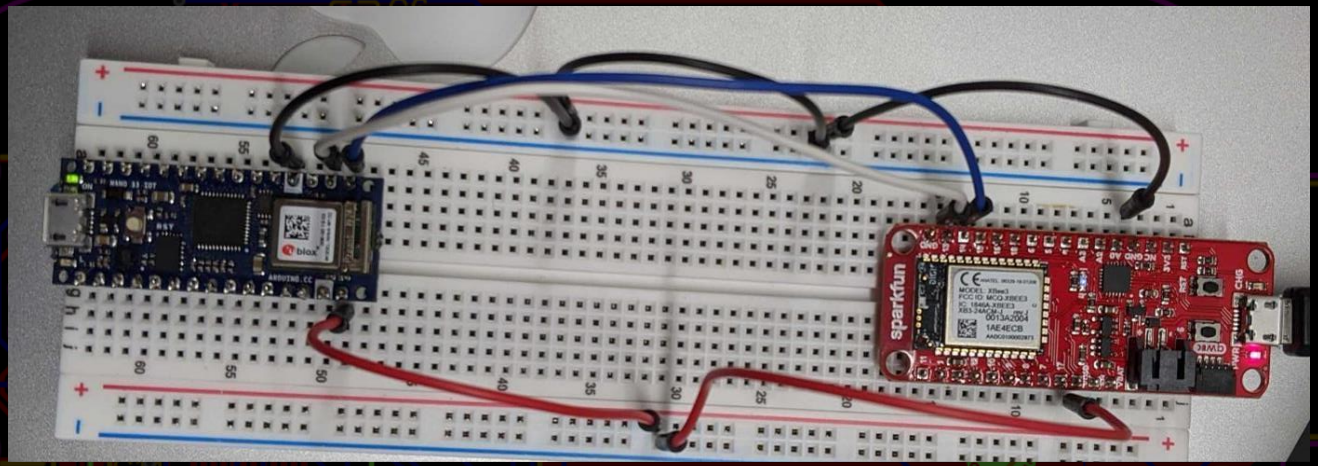
- Trinket M0
- Nano 33 IoT
- **SparkFun XBee3 Thing Plus board (x2)**



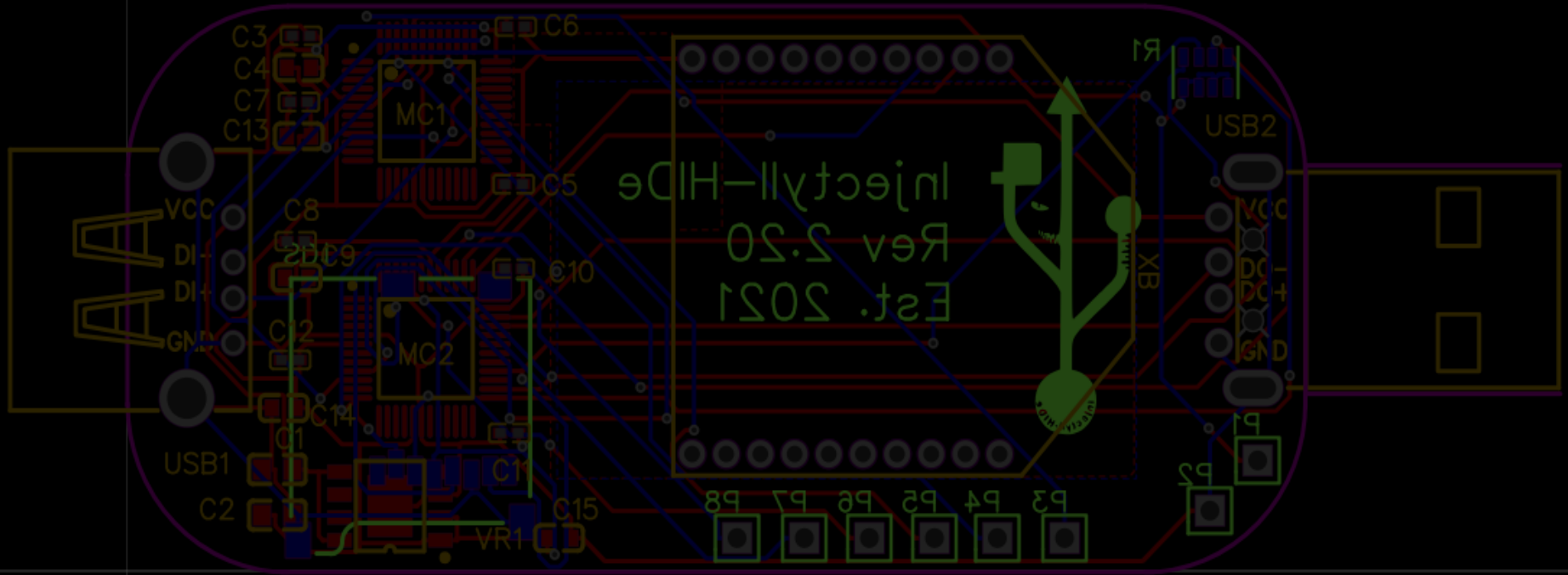
Prototype #1 Layout



Prototype #1



Prototype #1 Lessons Learned

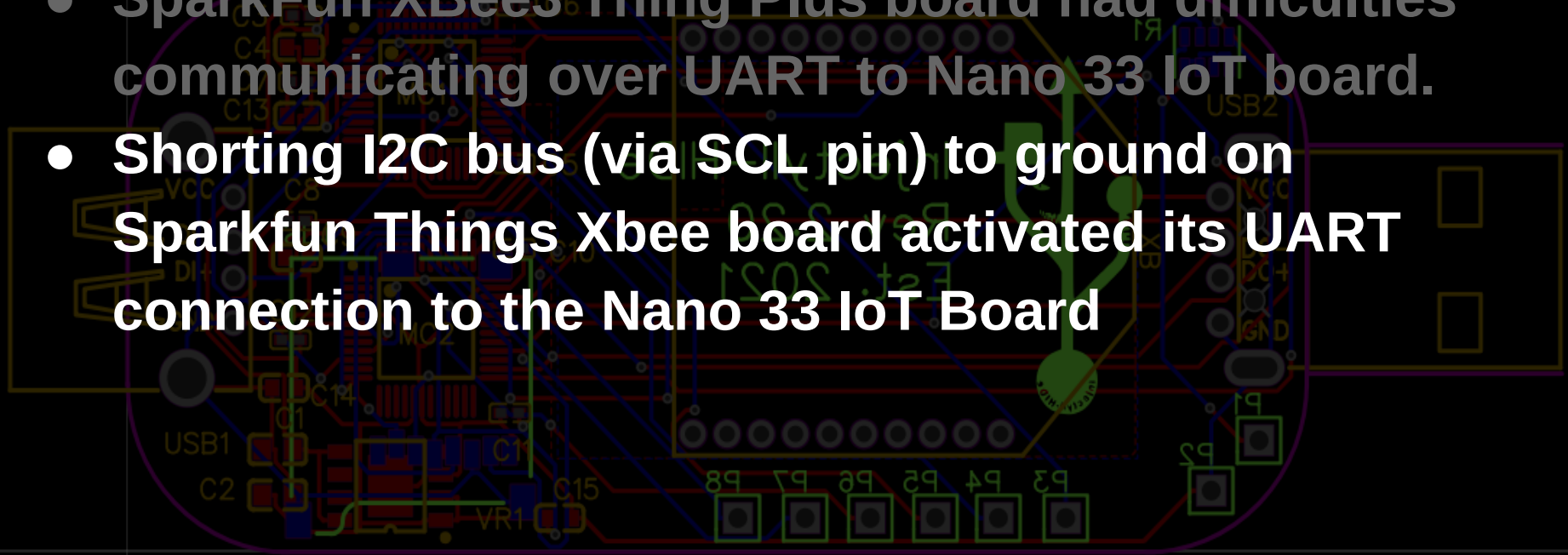


Prototype #1 Lessons Learned

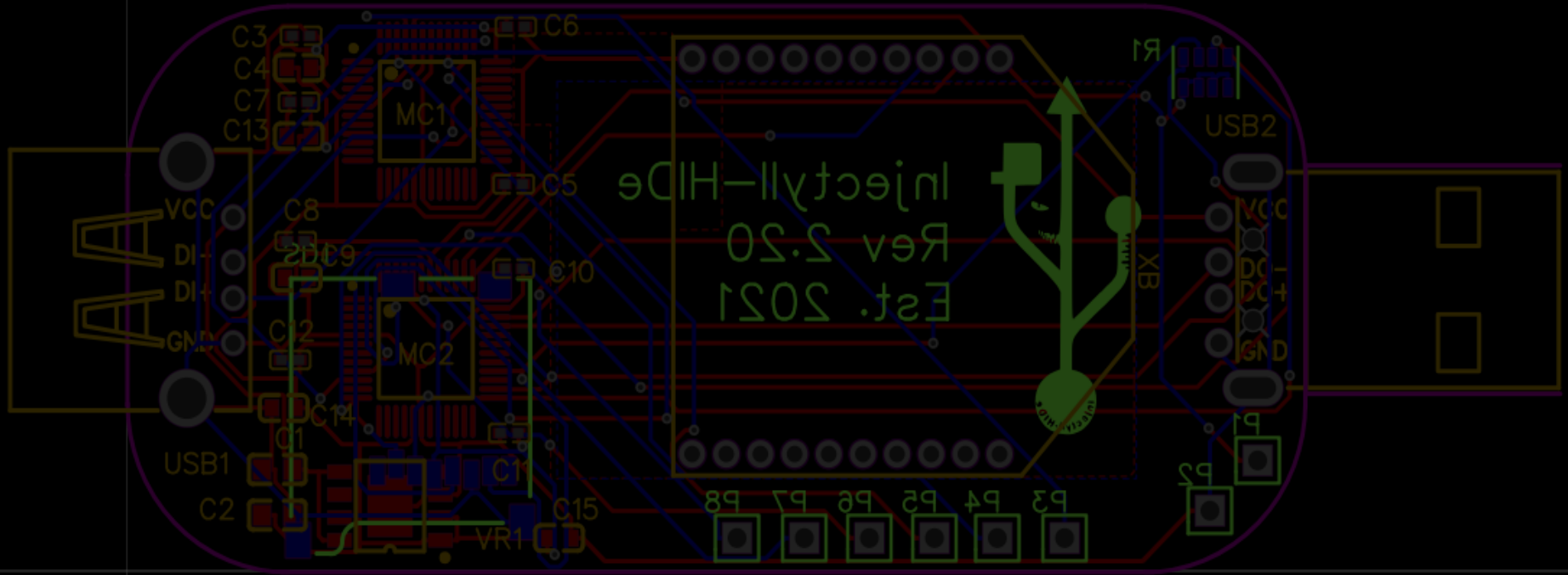
- **SparkFun XBee3 Thing Plus board had difficulties communicating over UART to Nano 33 IoT board.**

Prototype #1 Lessons Learned

- SparkFun XBee3 Thing Plus board had difficulties communicating over UART to Nano 33 IoT board.
- **Shorting I2C bus (via SCL pin) to ground on Sparkfun Things Xbee board activated its UART connection to the Nano 33 IoT Board**

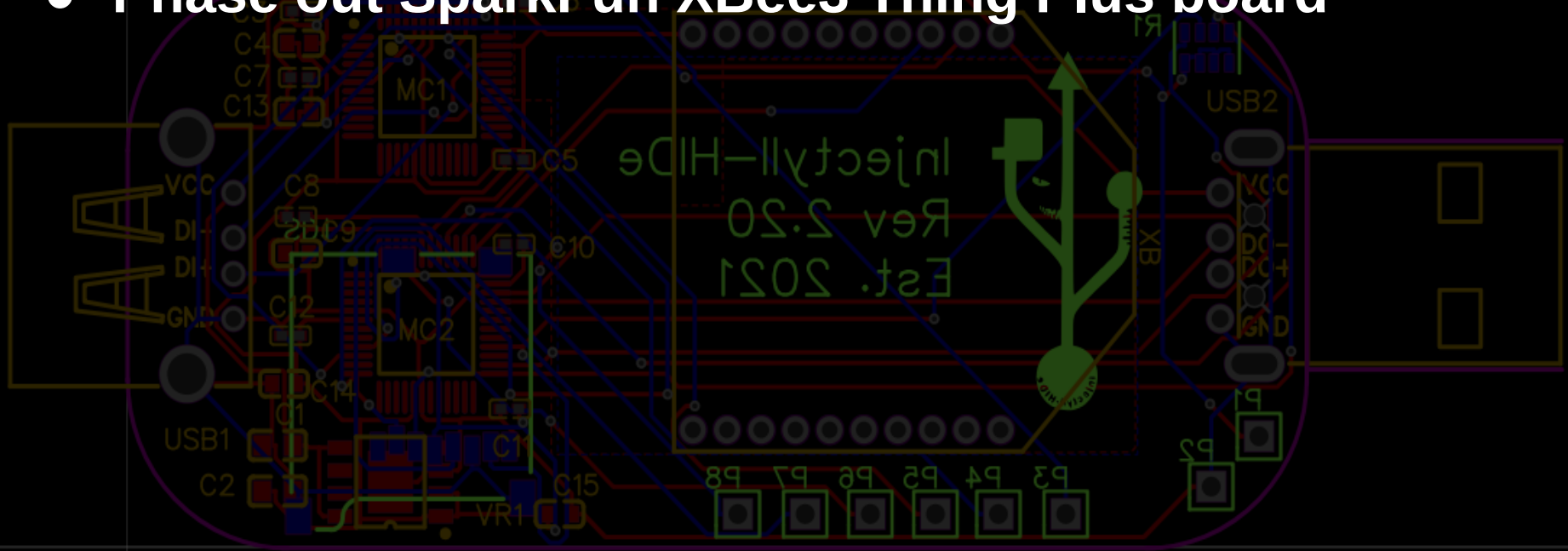


Prototype #1 Conclusions



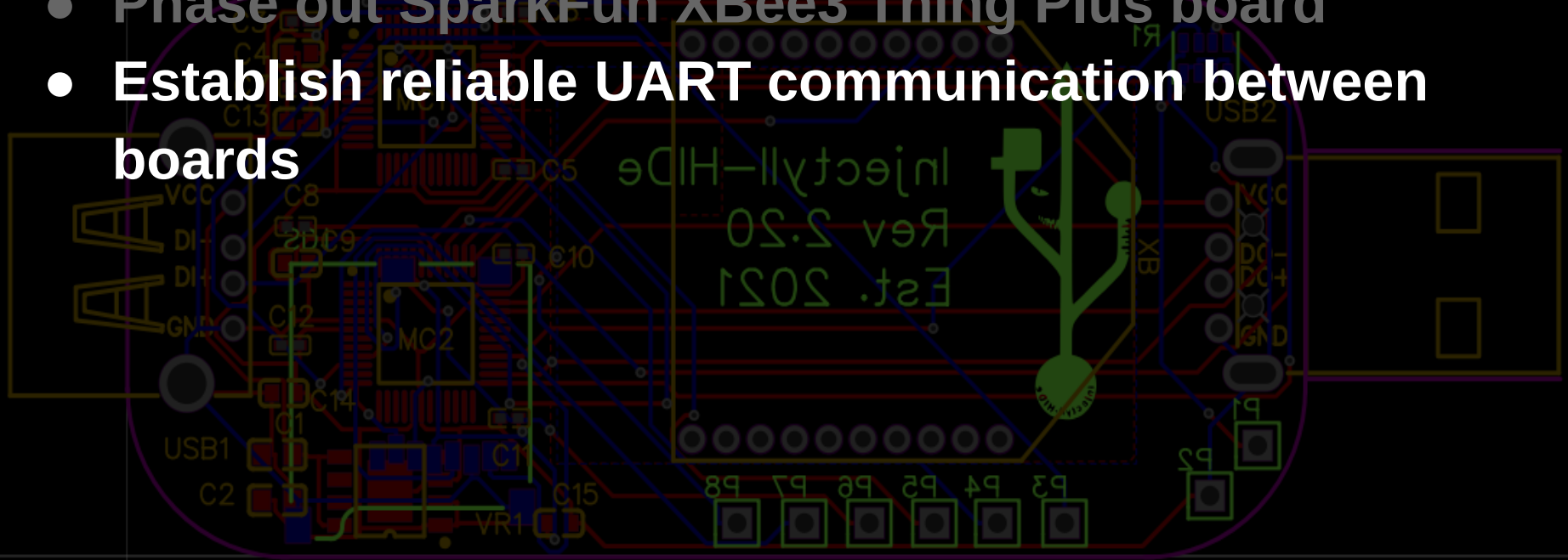
Prototype #1 Conclusions

- **Phase out SparkFun XBee3 Thing Plus board**



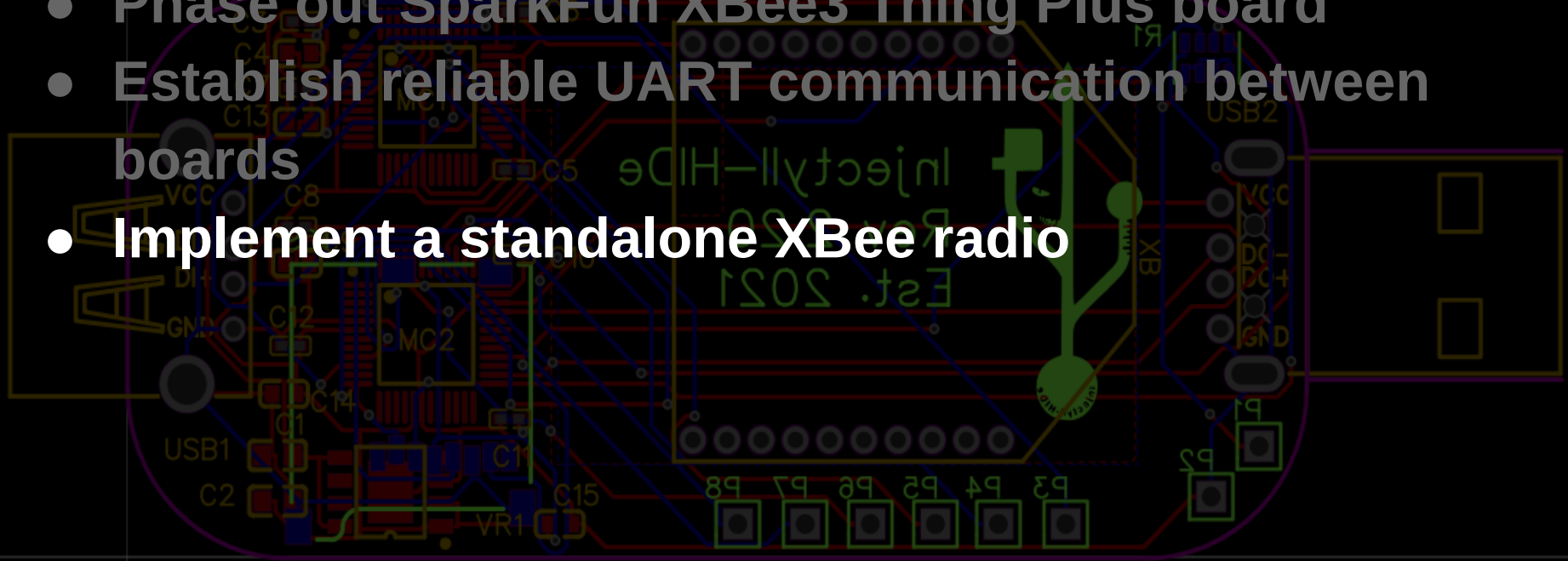
Prototype #1 Conclusions

- Phase out SparkFun XBee3 Thing Plus board
- **Establish reliable UART communication between boards**

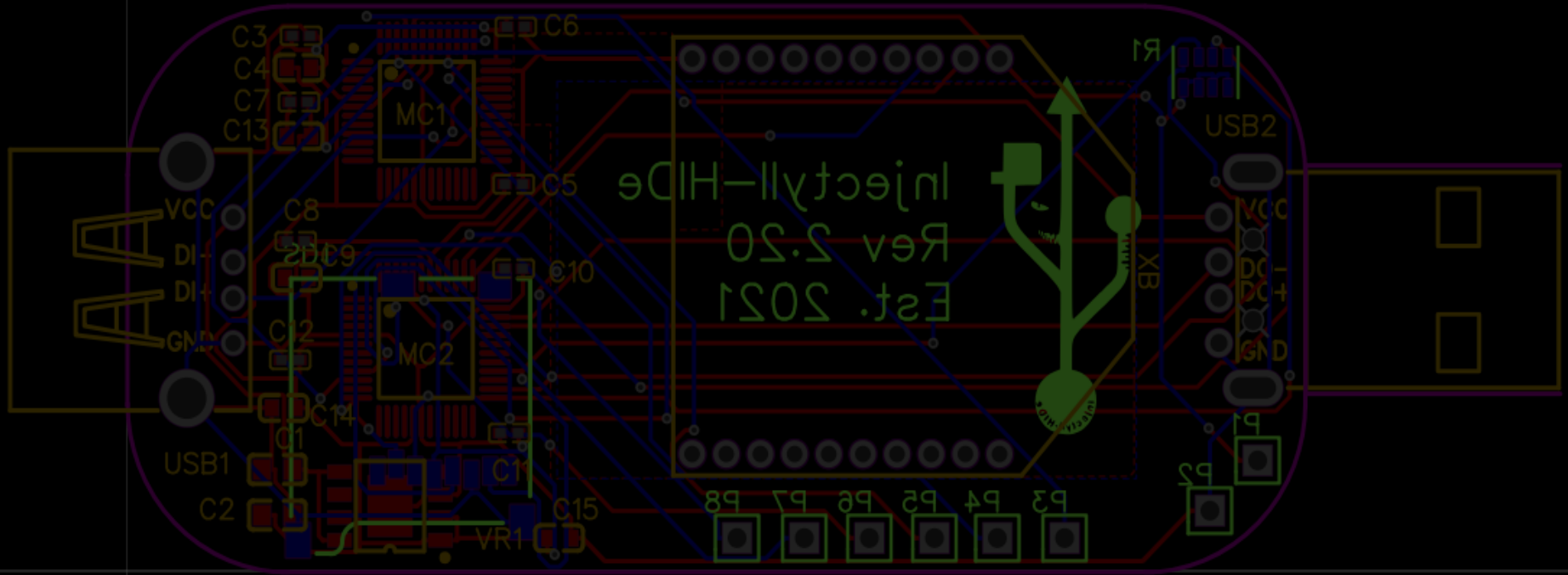


Prototype #1 Conclusions

- Phase out SparkFun XBee3 Thing Plus board
- Establish reliable UART communication between boards
- **Implement a standalone XBee radio**

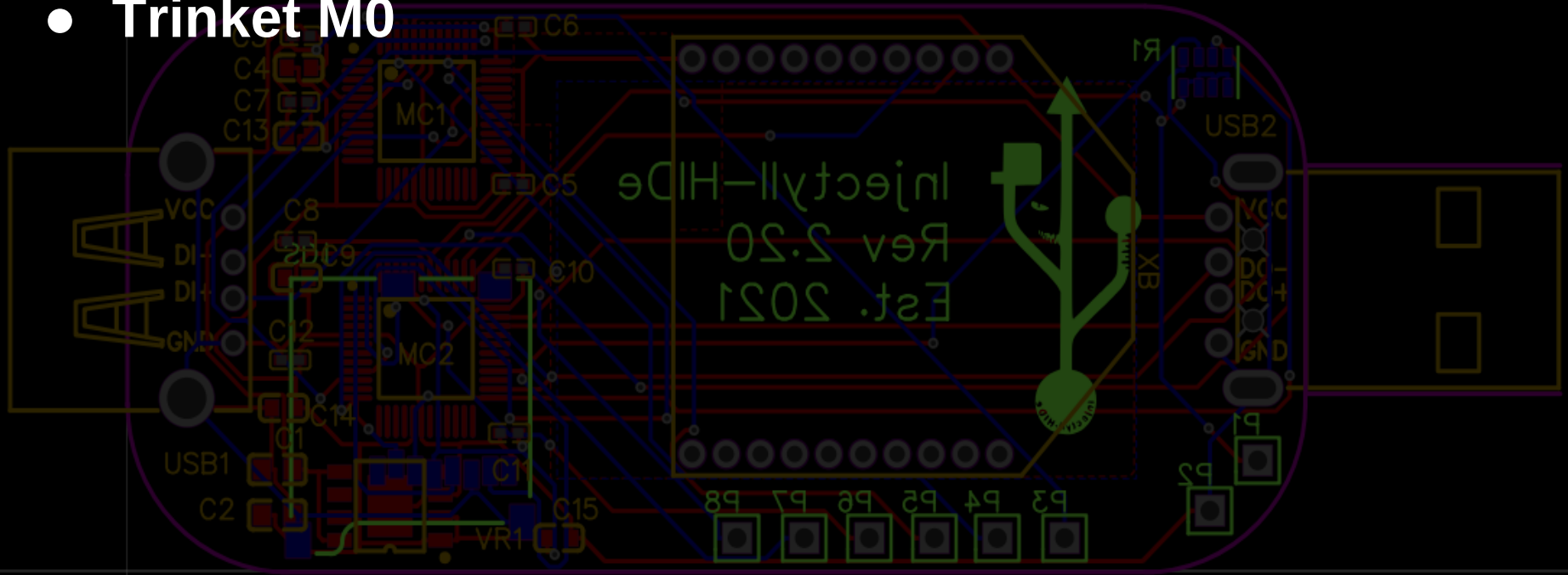


Prototype #2


C3
C4
C7
C13
C6
MC1
C5
C8
C9
C10
MC2
C12
C14
C1
C11
C15
VR1
USB1
C2
VCC
DI-
DI+
GND
P8 P7 P6 P5 P4 P3
R1
USB2
P1
P2
Injectyll-HIDe
Rev 2.20
Est. 2021

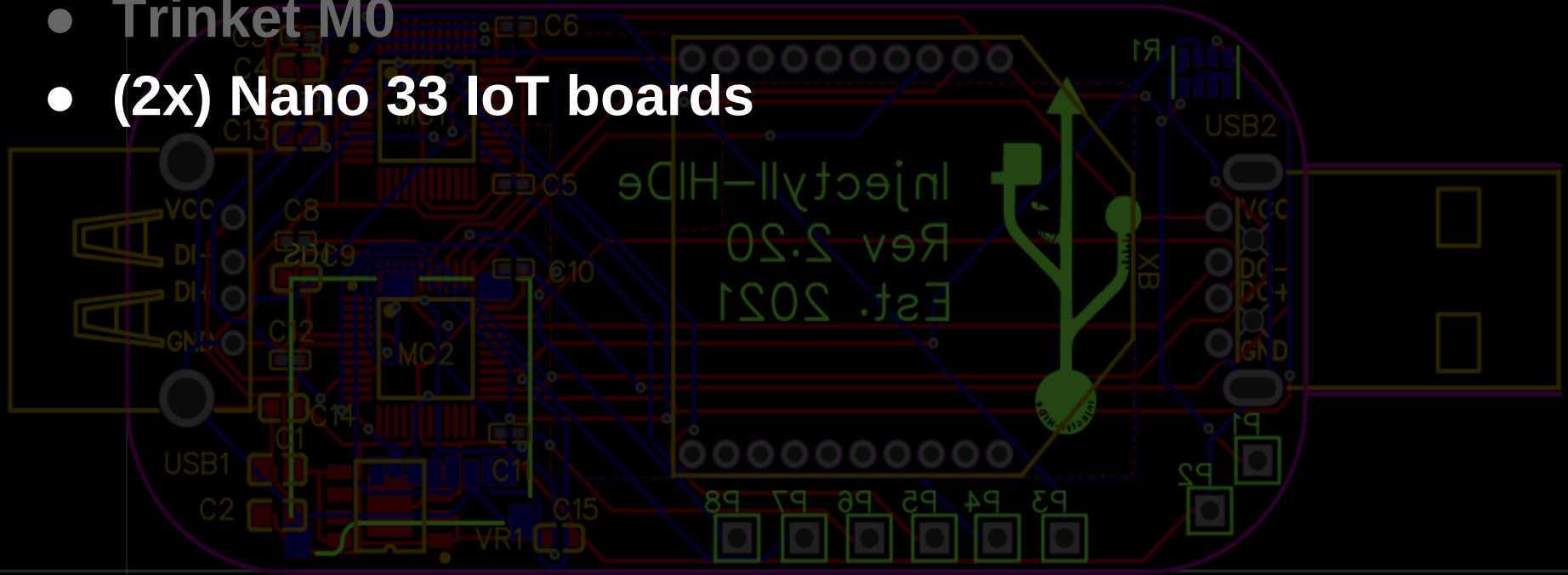
Prototype #2

- **Trinket M0**



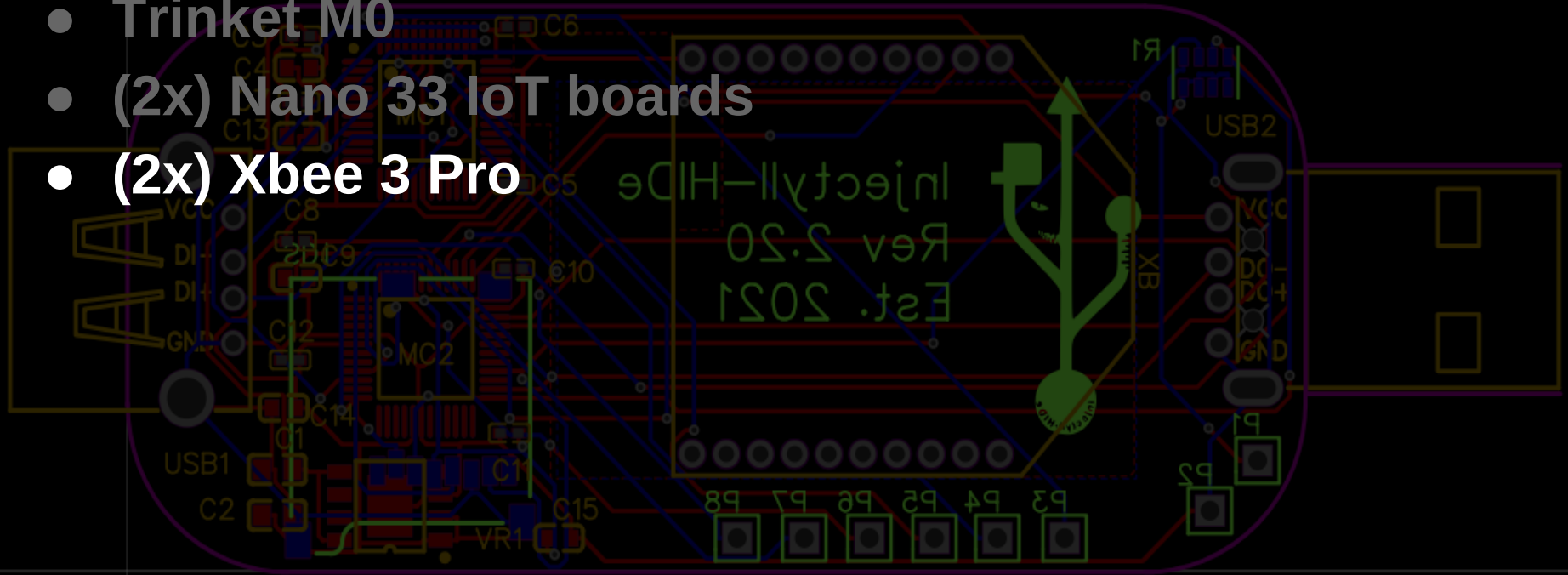
Prototype #2

- Trinket M0
- (2x) Nano 33 IoT boards

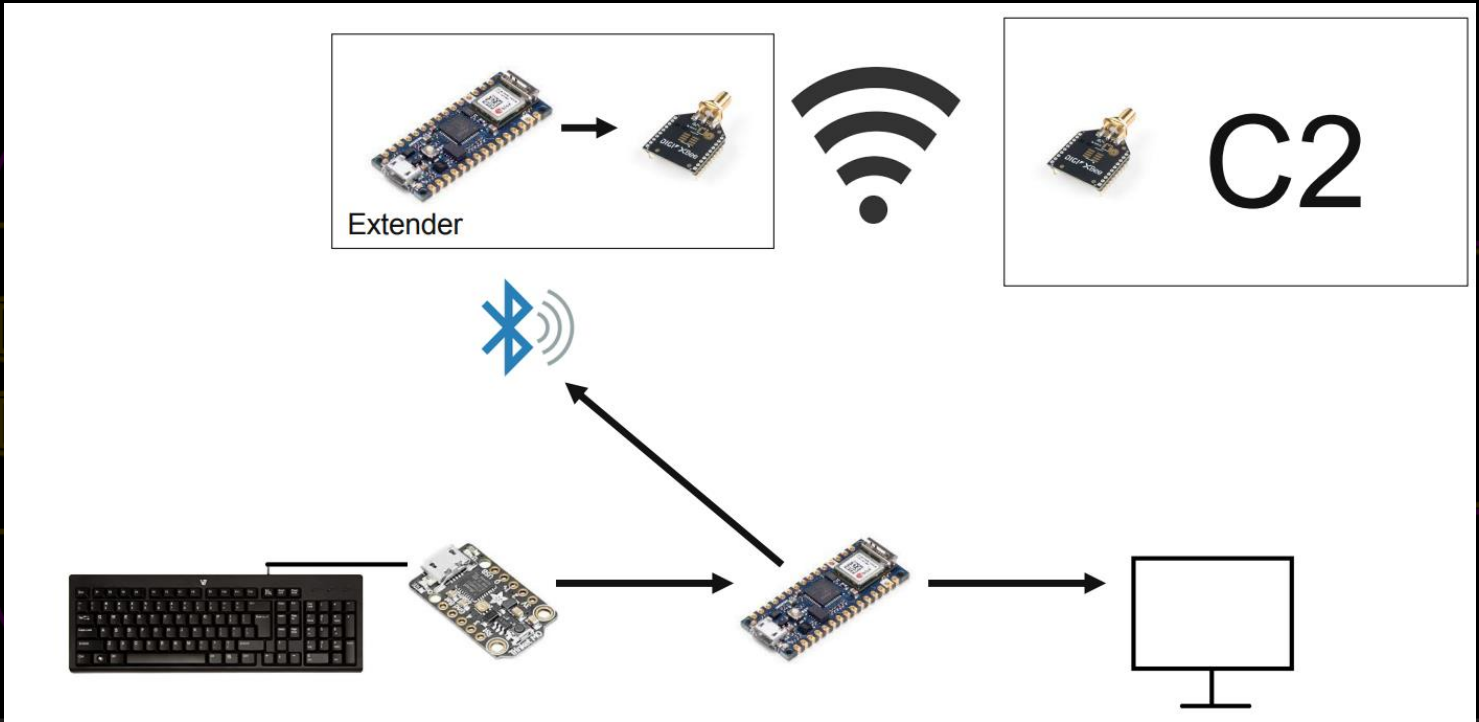


Prototype #2

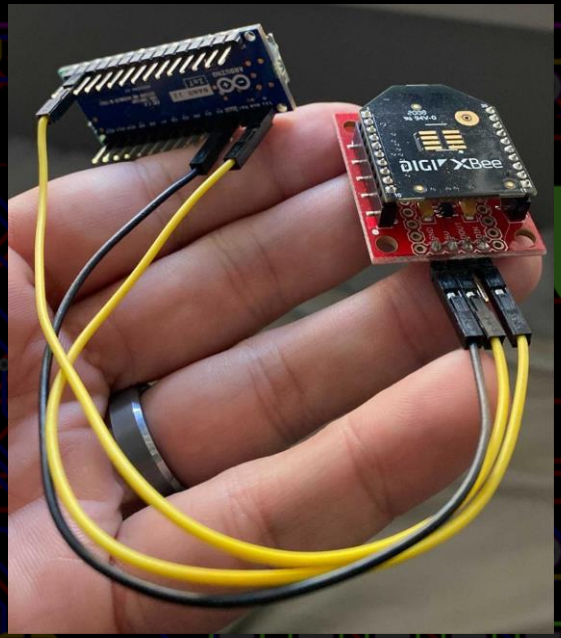
- Trinket M0
- (2x) Nano 33 IoT boards
- **(2x) Xbee 3 Pro**



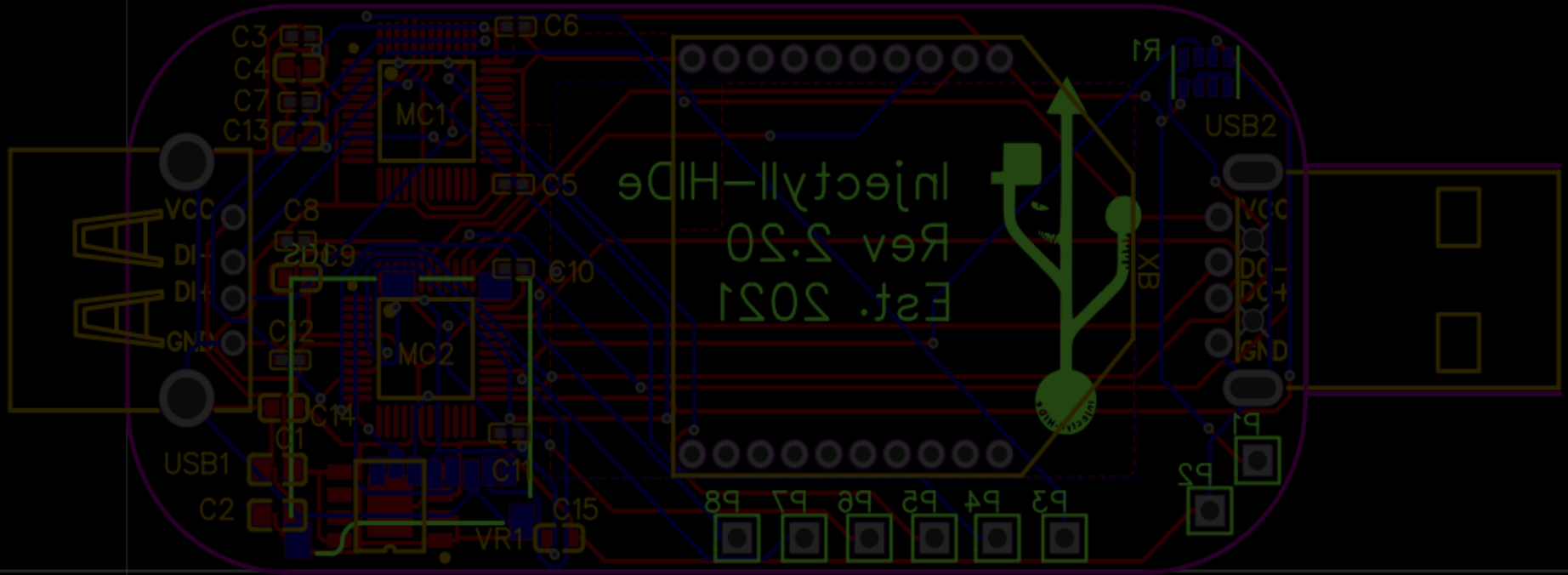
Prototype #2 Layout



Prototype #2

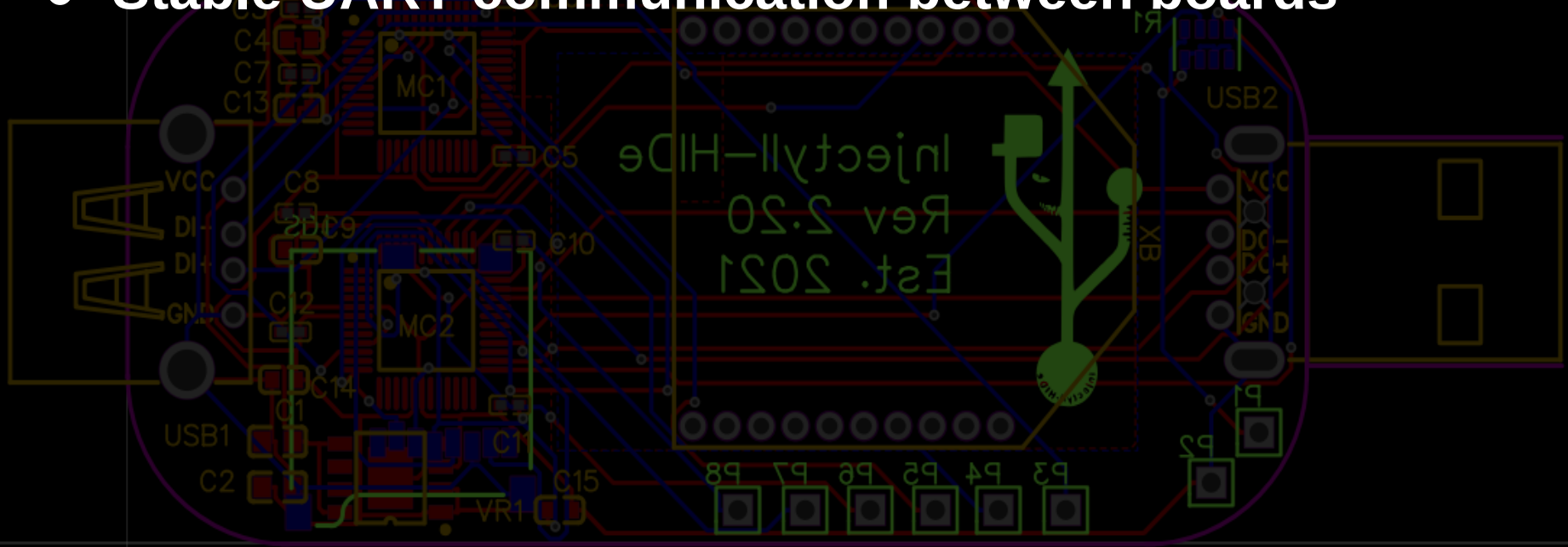


Prototype #2 Lessons Learned



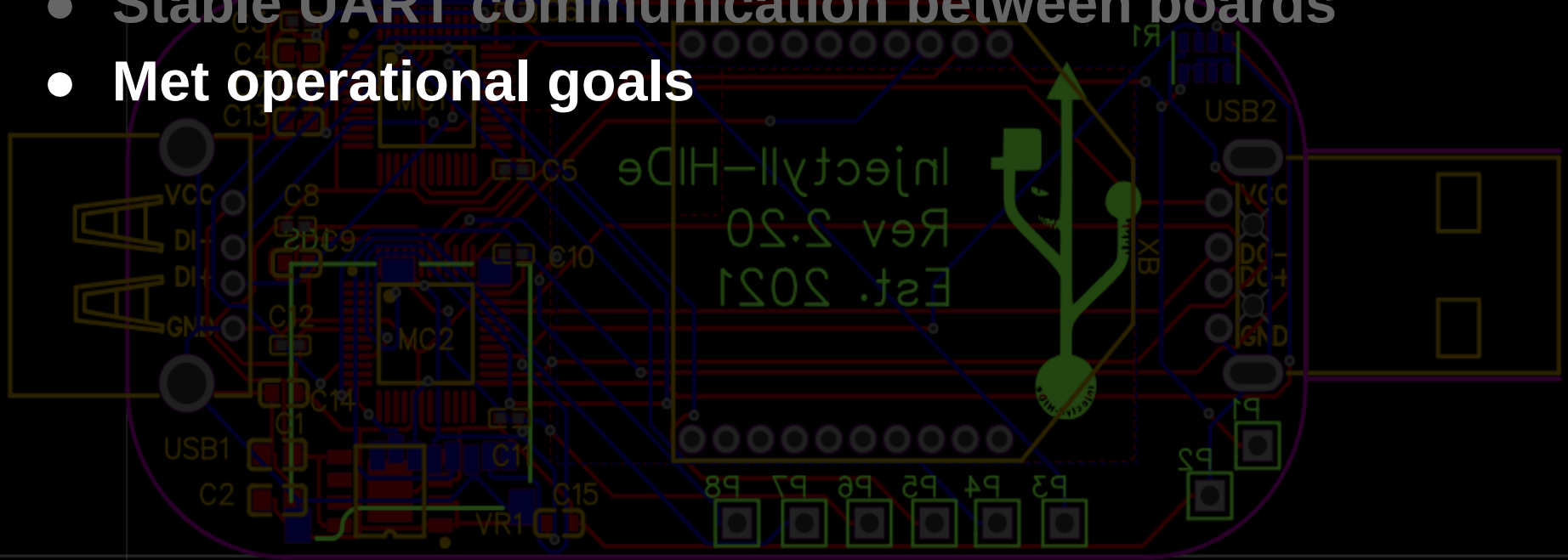
Prototype #2 Lessons Learned

- **Stable UART communication between boards**

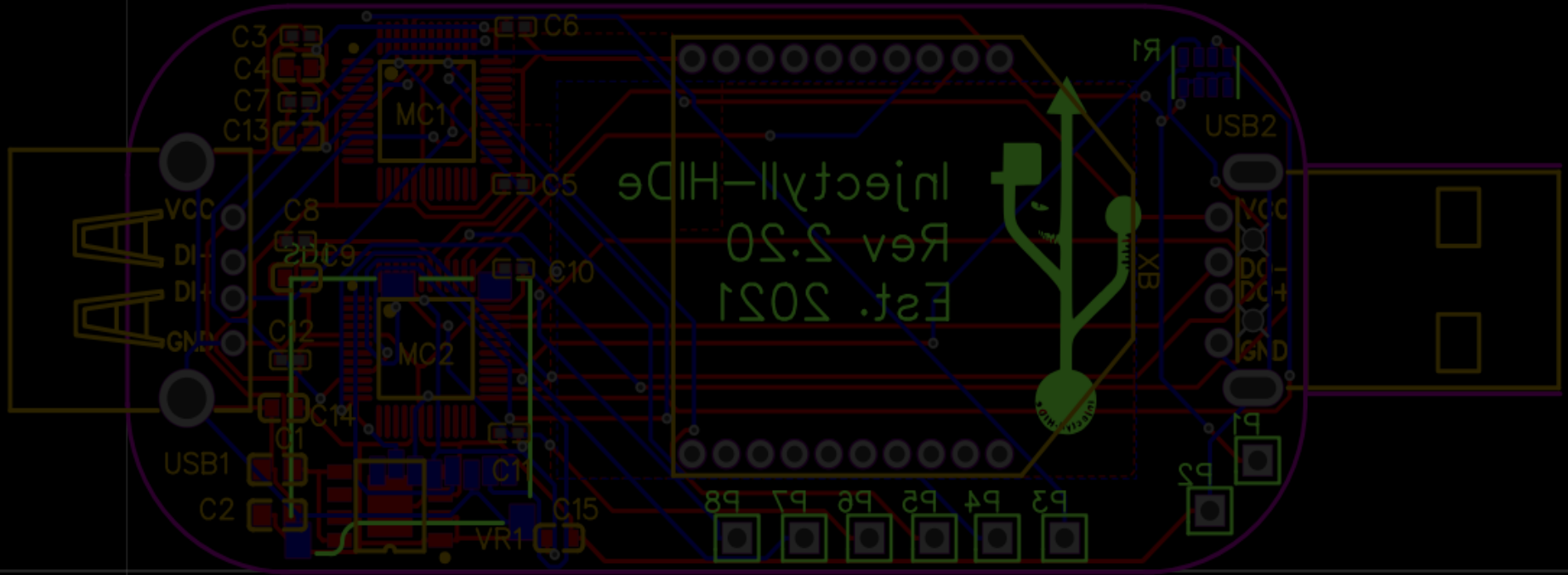


Prototype #2 Lessons Learned

- Stable UART communication between boards
- **Met operational goals**

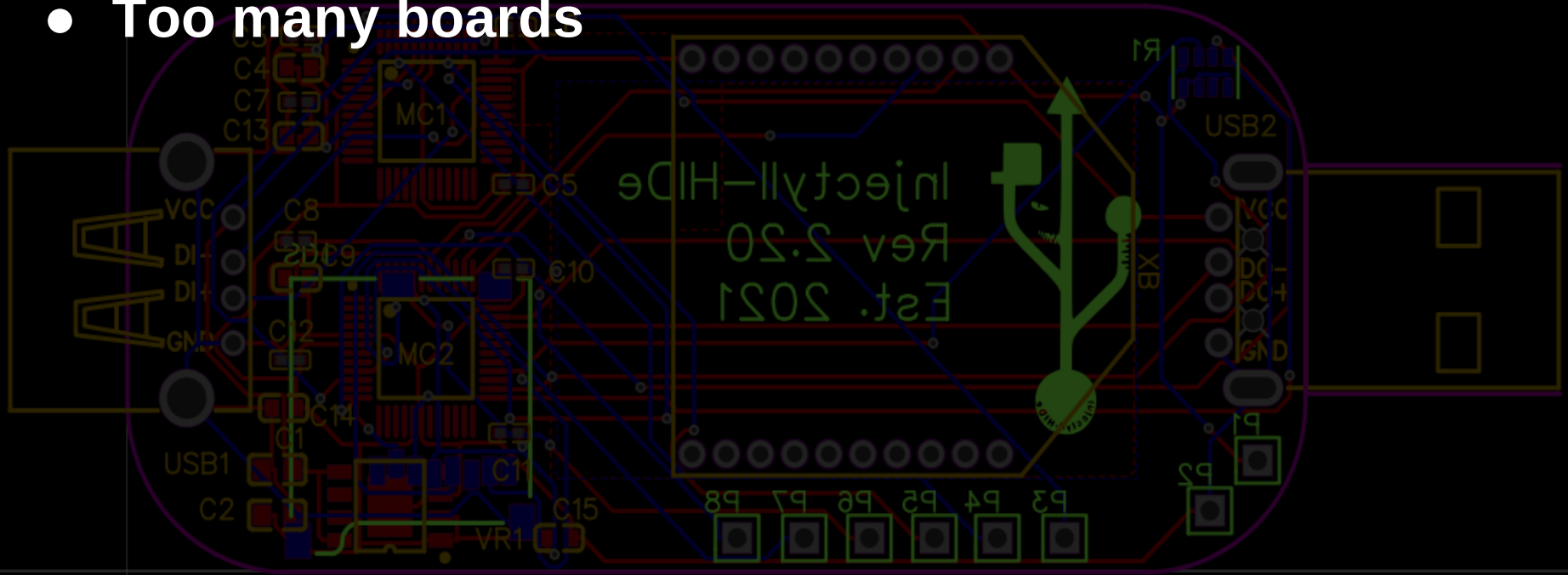


Prototype #2 Conclusions



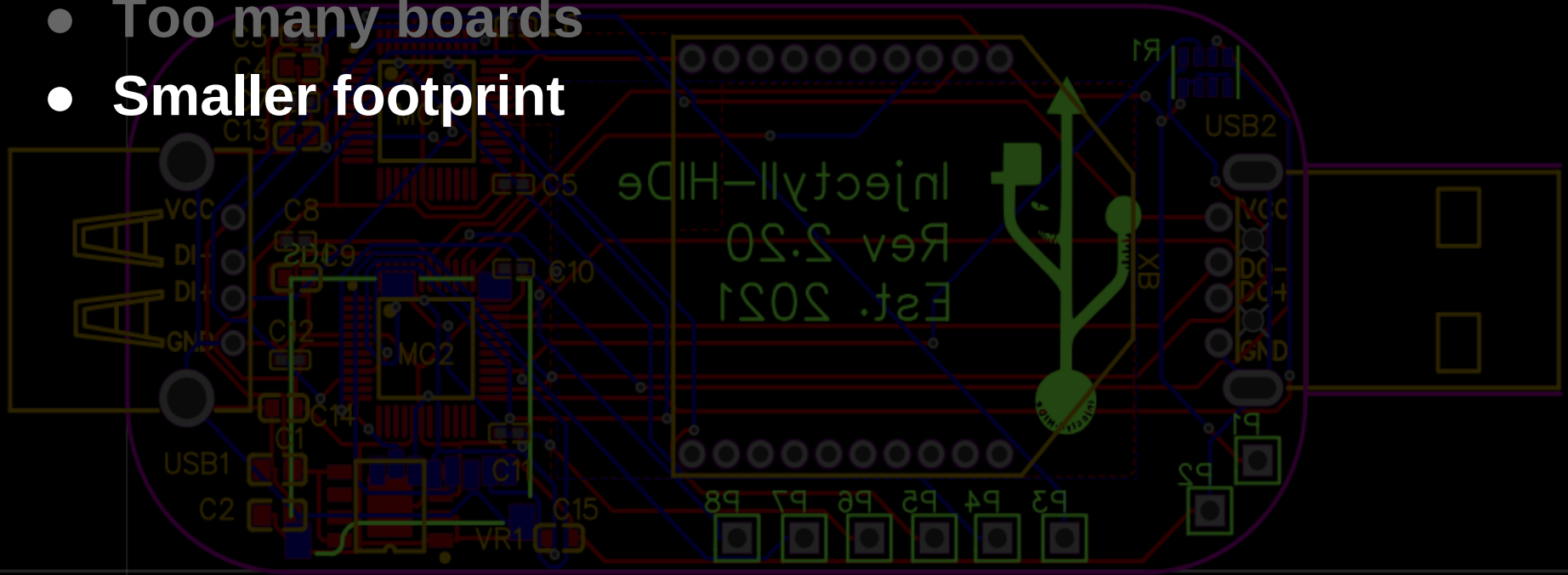
Prototype #2 Conclusions

- **Too many boards**



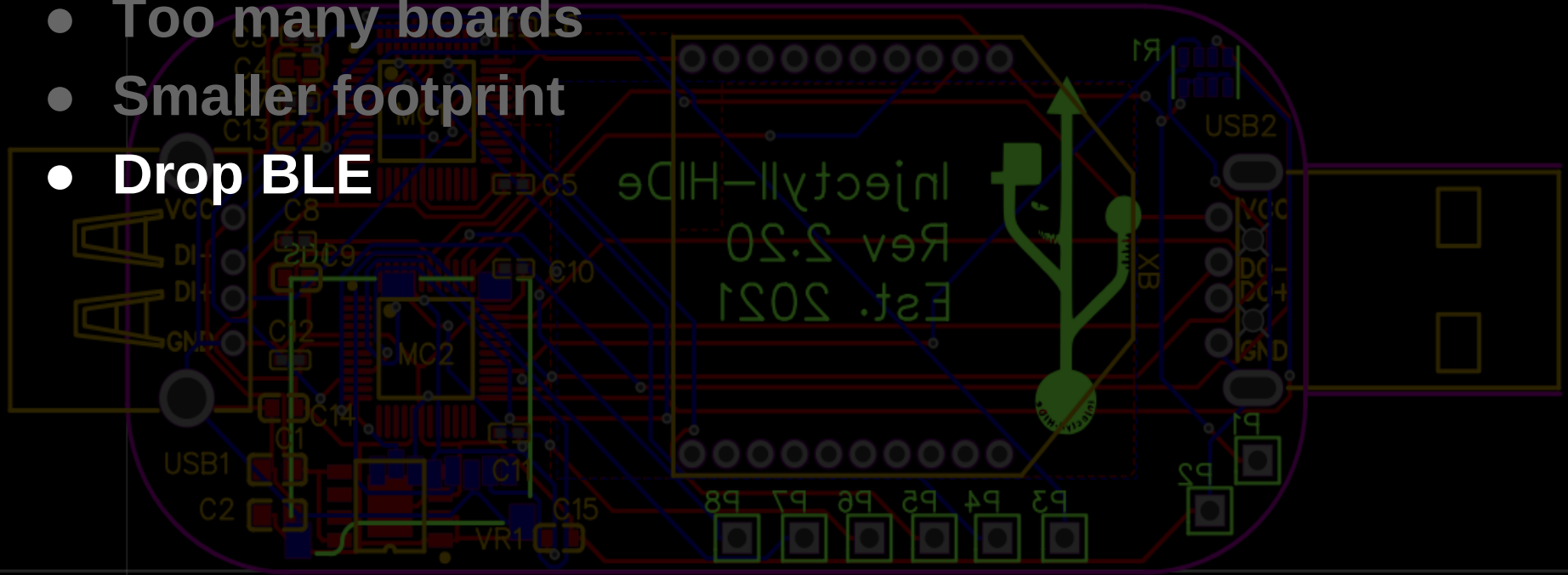
Prototype #2 Conclusions

- Too many boards
- **Smaller footprint**



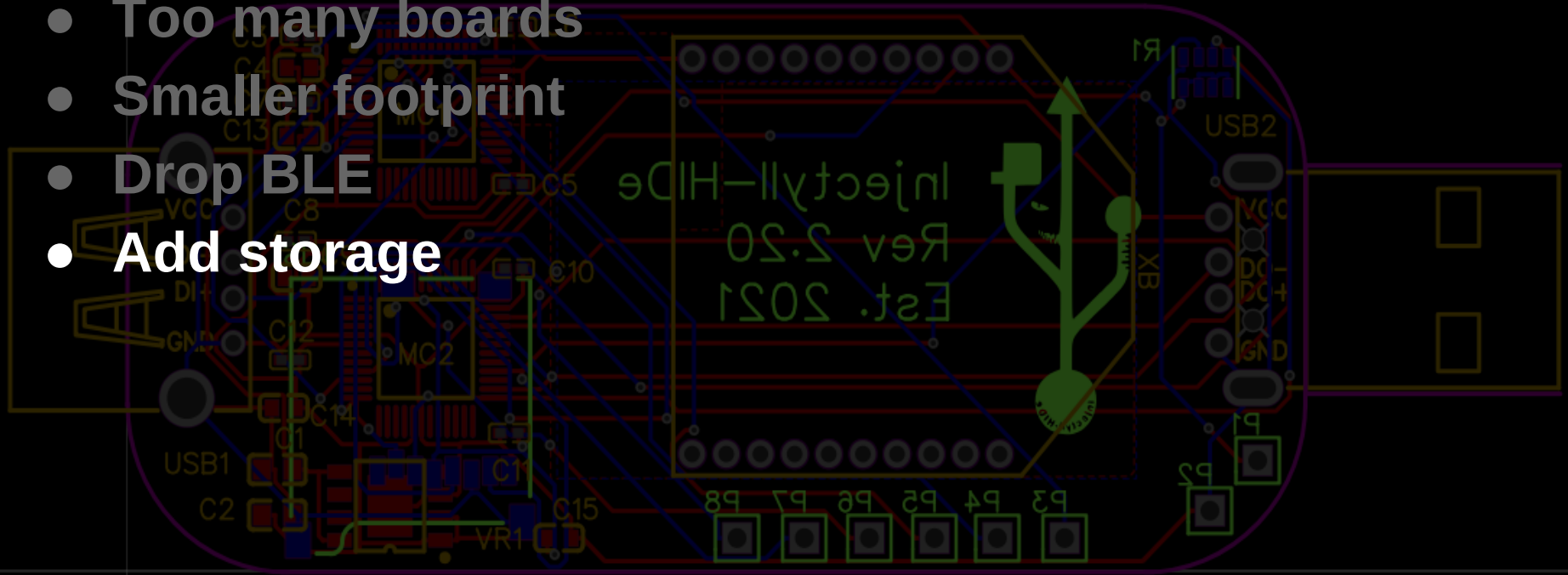
Prototype #2 Conclusions

- Too many boards
- Smaller footprint
- **Drop BLE**

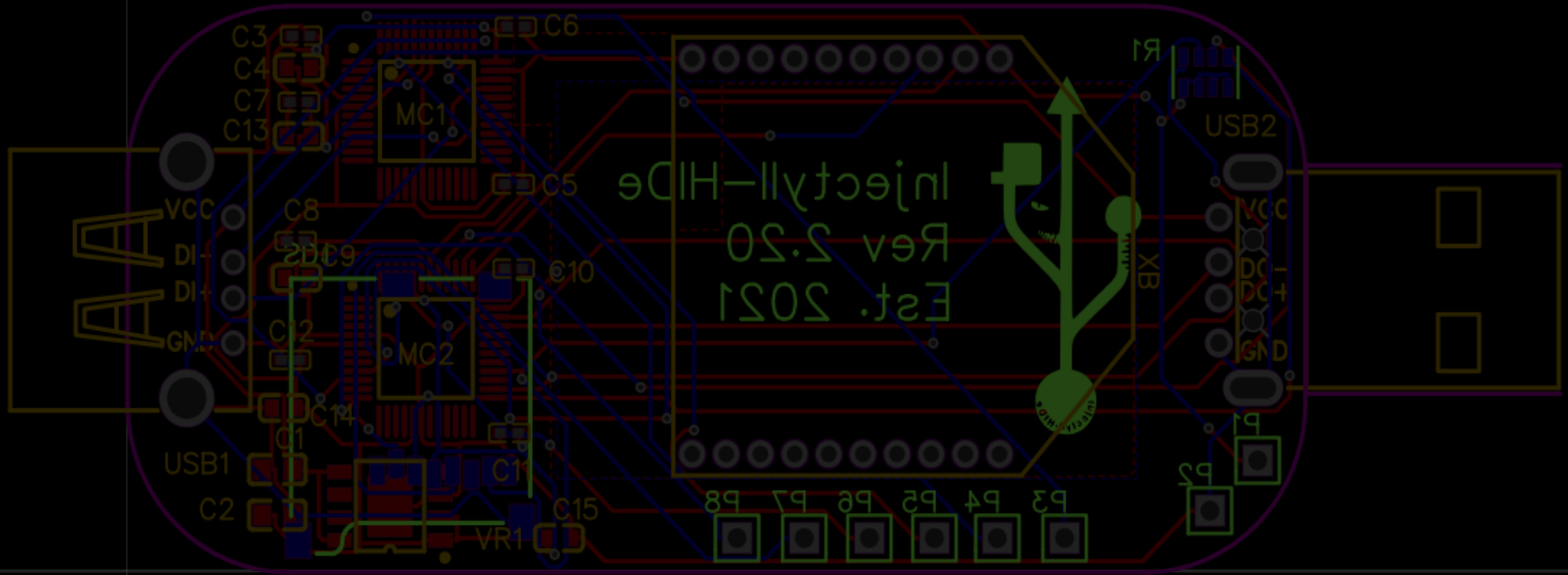


Prototype #2 Conclusions

- Too many boards
- Smaller footprint
- Drop BLE
- **Add storage**

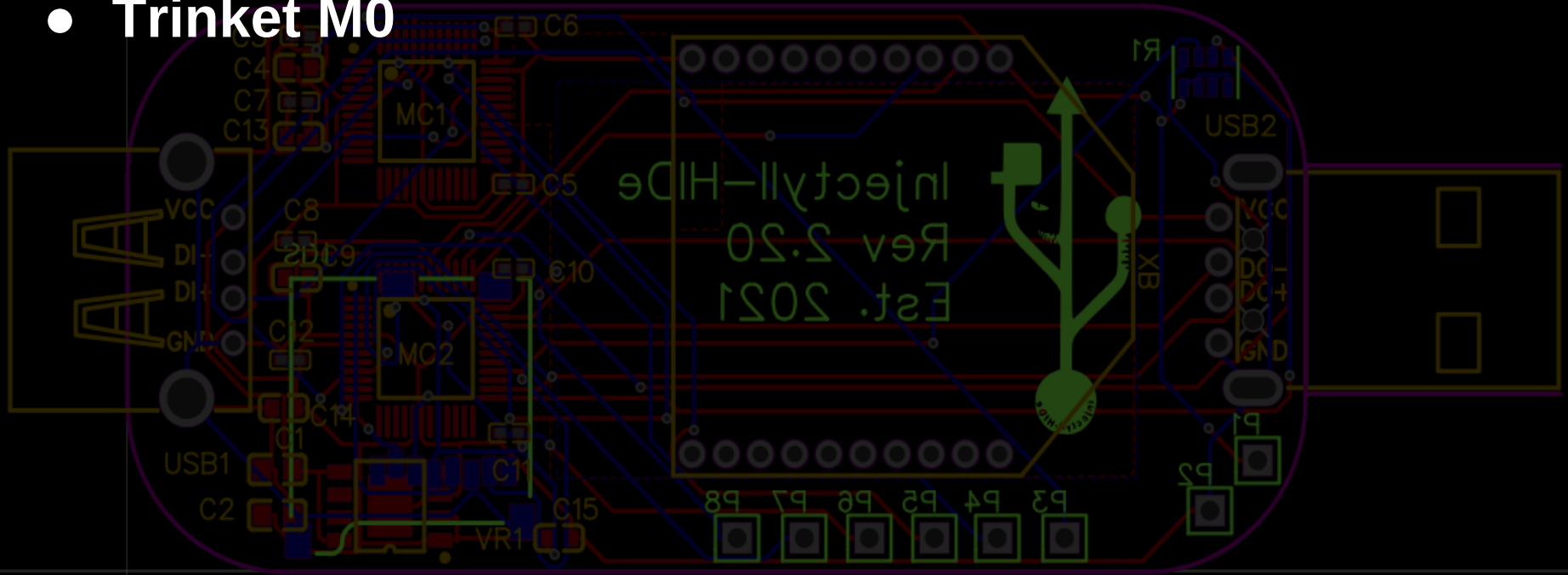


Prototype #3


C3
C4
C7
C13
C6
MC1
C5
C8
C9
C10
MC2
C12
C14
C1
C11
C15
VR1
USB1
C2
VCC
DI-
DI+
GND
Injectyll-HIDe
Rev 2.20
Est. 2021
R1
USB2
VCC
D-
D+
GND
P1
P2
P3
P4
P5
P6
P7
P8

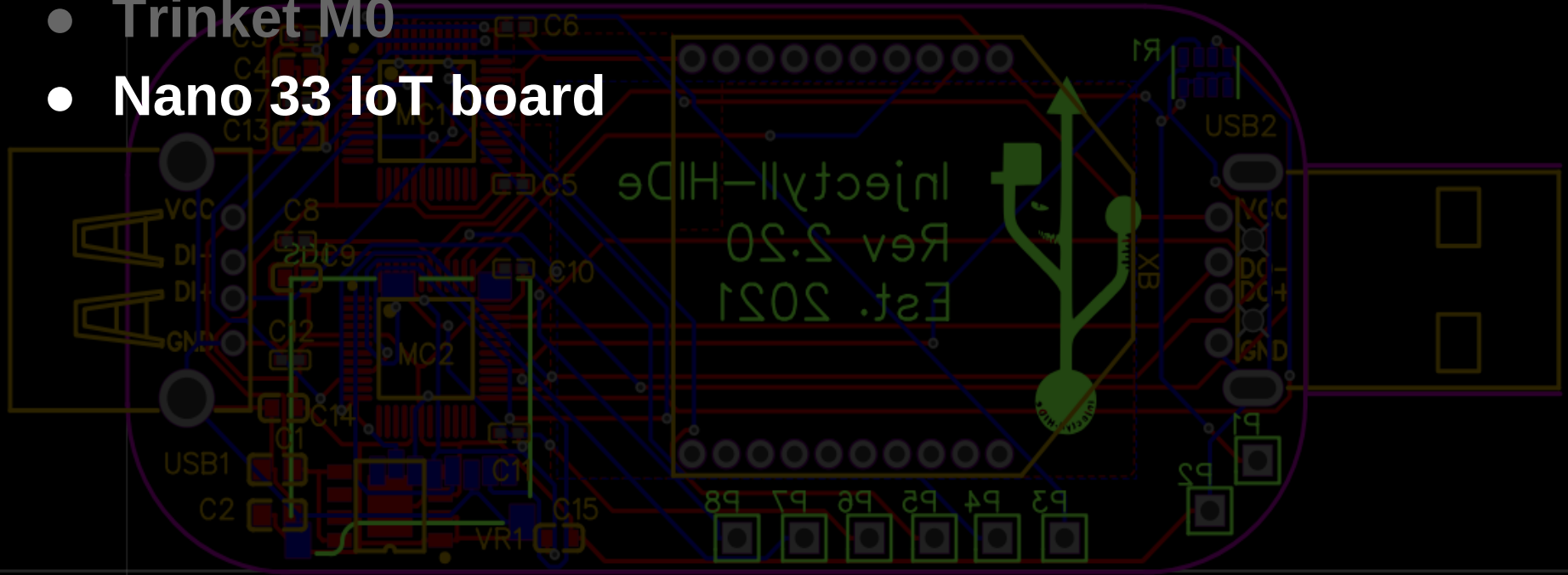
Prototype #3

- **Trinket M0**



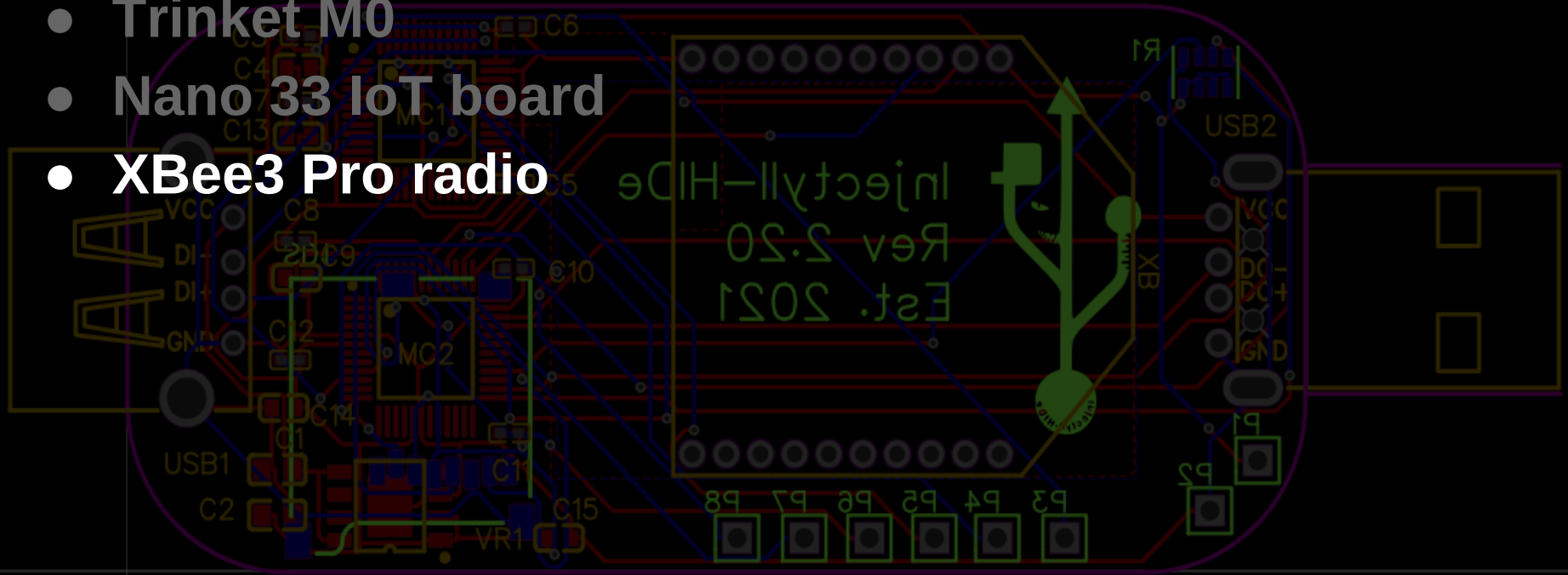
Prototype #3

- Trinket M0
- **Nano 33 IoT board**



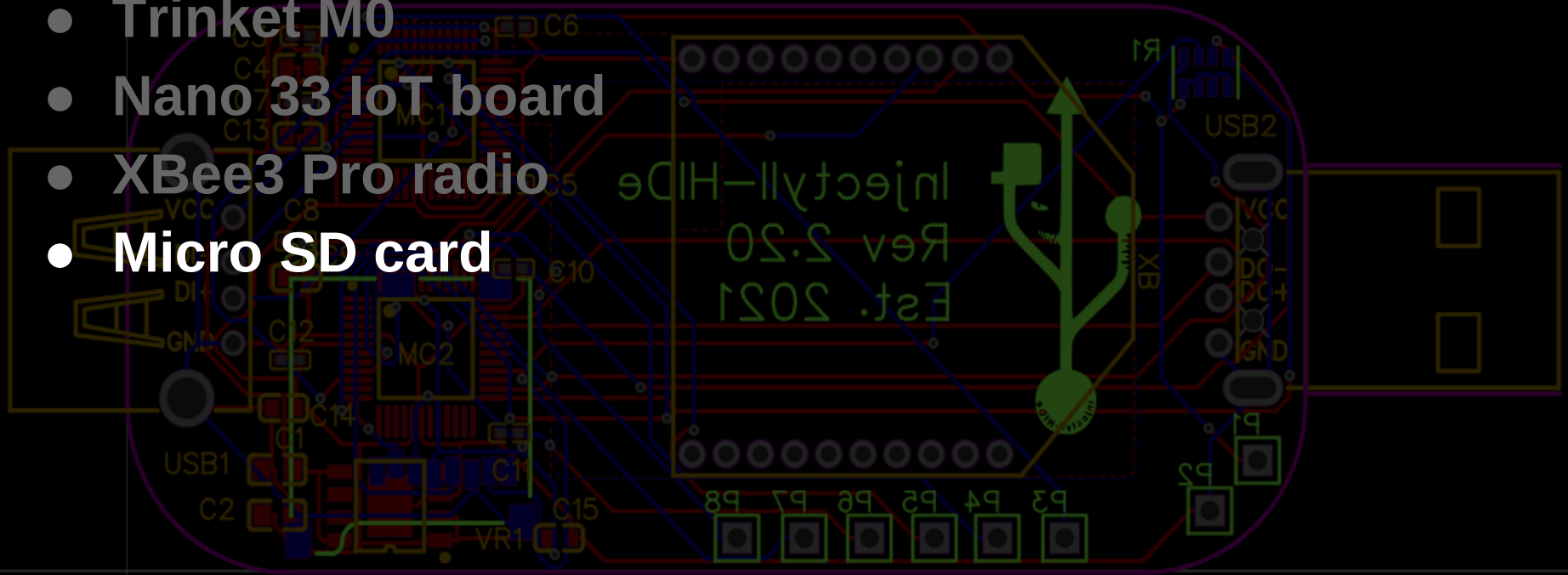
Prototype #3

- Trinket M0
- Nano 33 IoT board
- **XBee3 Pro radio**

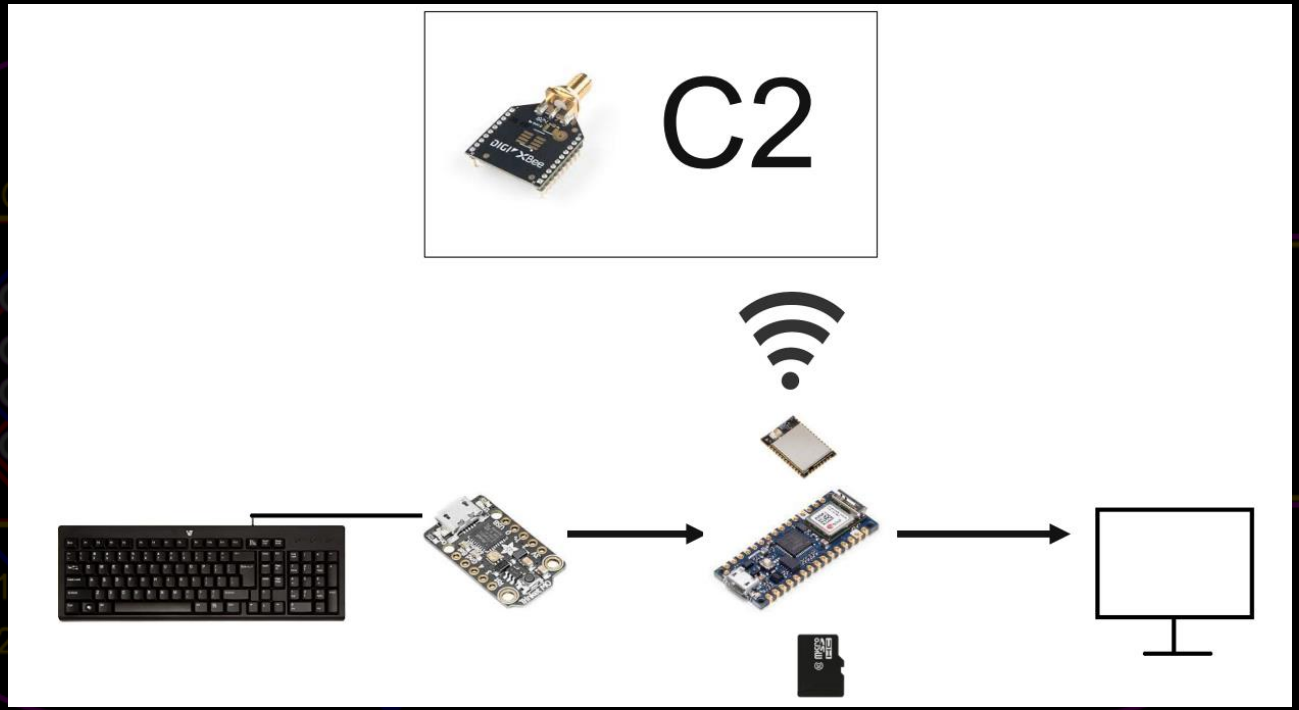


Prototype #3

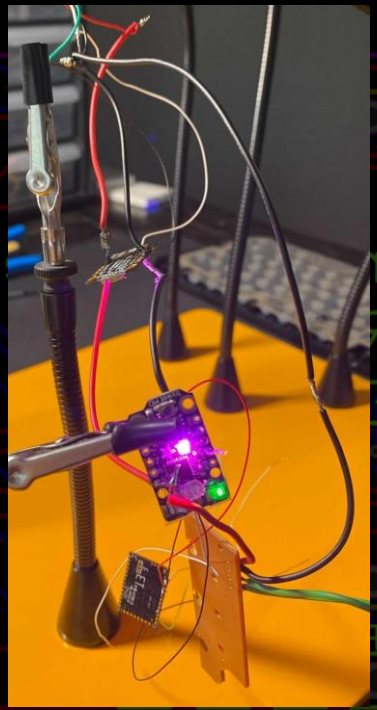
- Trinket M0
- Nano 33 IoT board
- XBee3 Pro radio
- **Micro SD card**



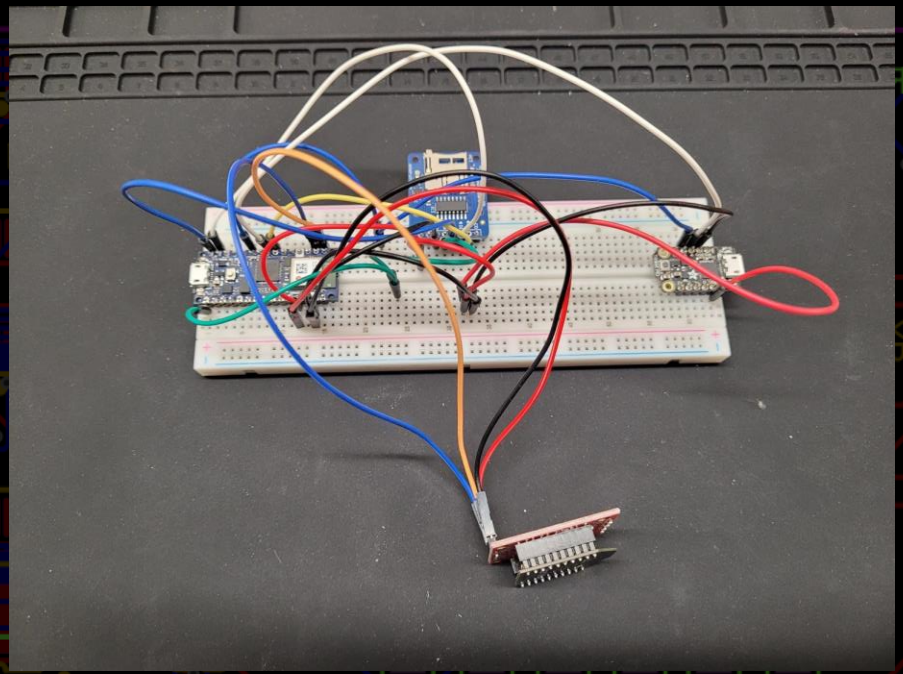
Prototype #3 Layout



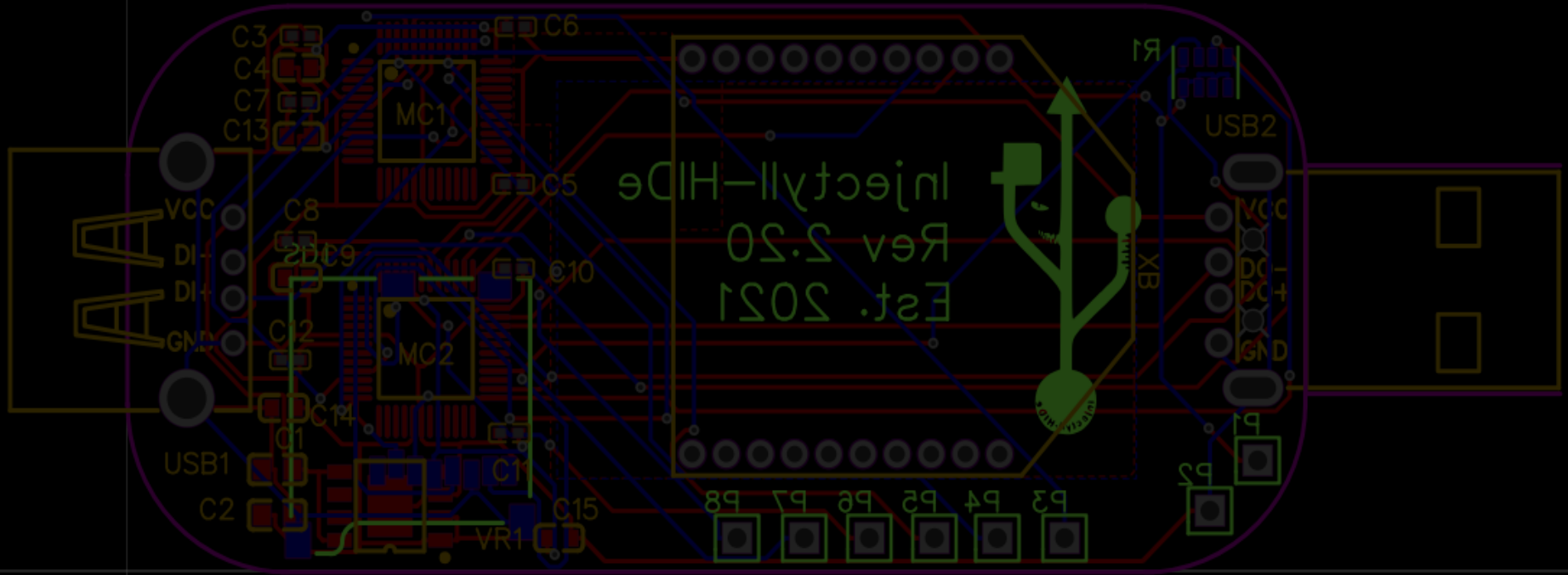
Prototype #3



Prototype #3



Prototype #3 Lessons Learned



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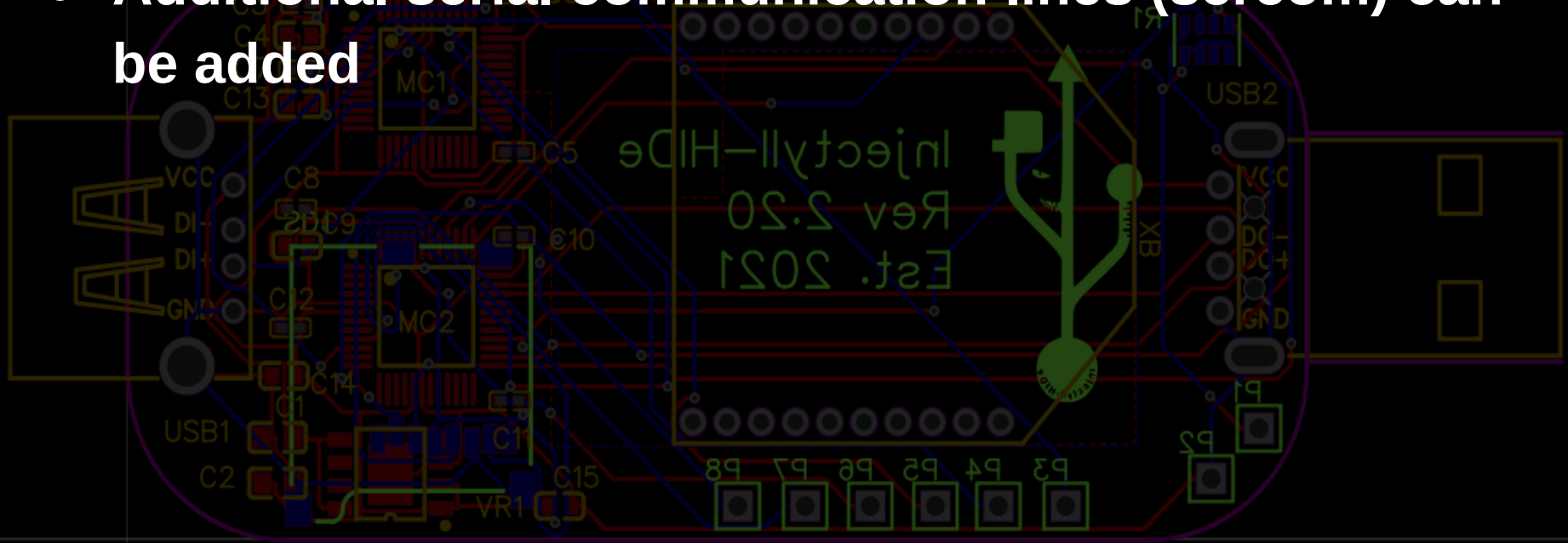
Prototype #3 Lessons Learned

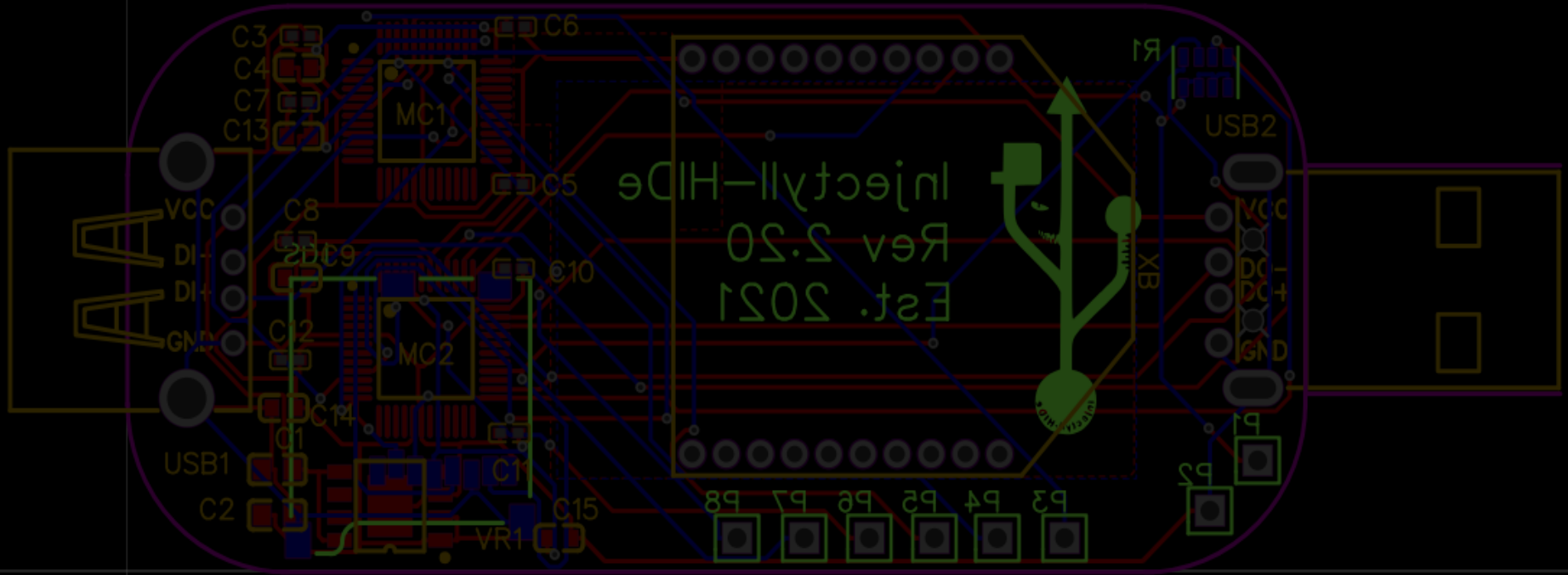
- **Additional serial communication lines (sercom) can be added**



Prototype #3 Lessons Learned

- Additional serial communication lines (sercom) can be added
- **Pay attention to the variant.cpp mapping file!**

Prototype #3 Conclusions



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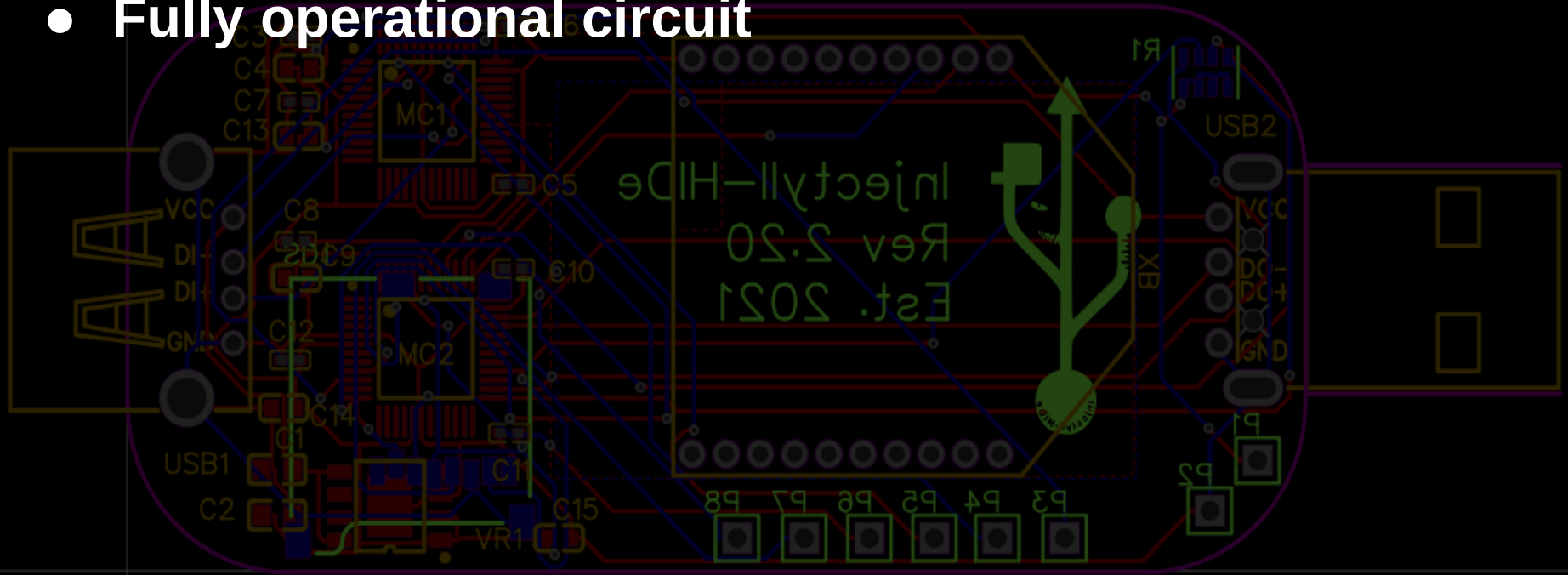
@Injectyll_HIDe

@allTheJurm

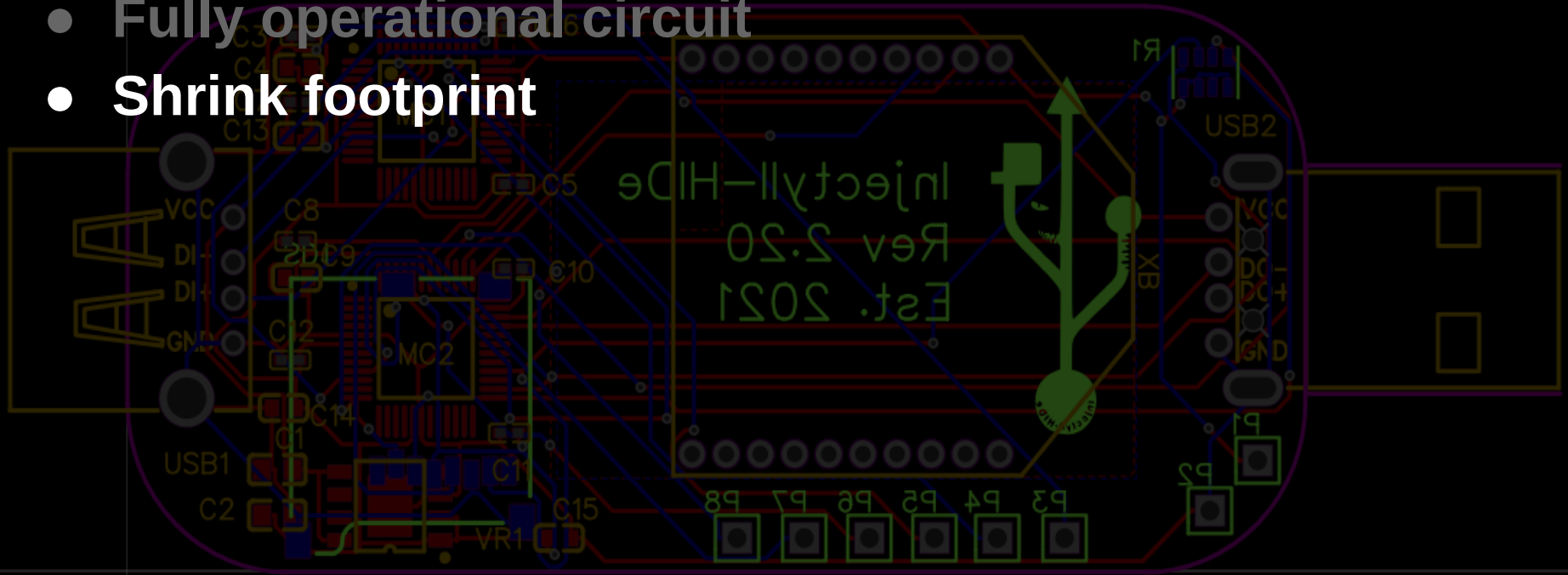
Prototype #3 Conclusions

- **Fully operational circuit**



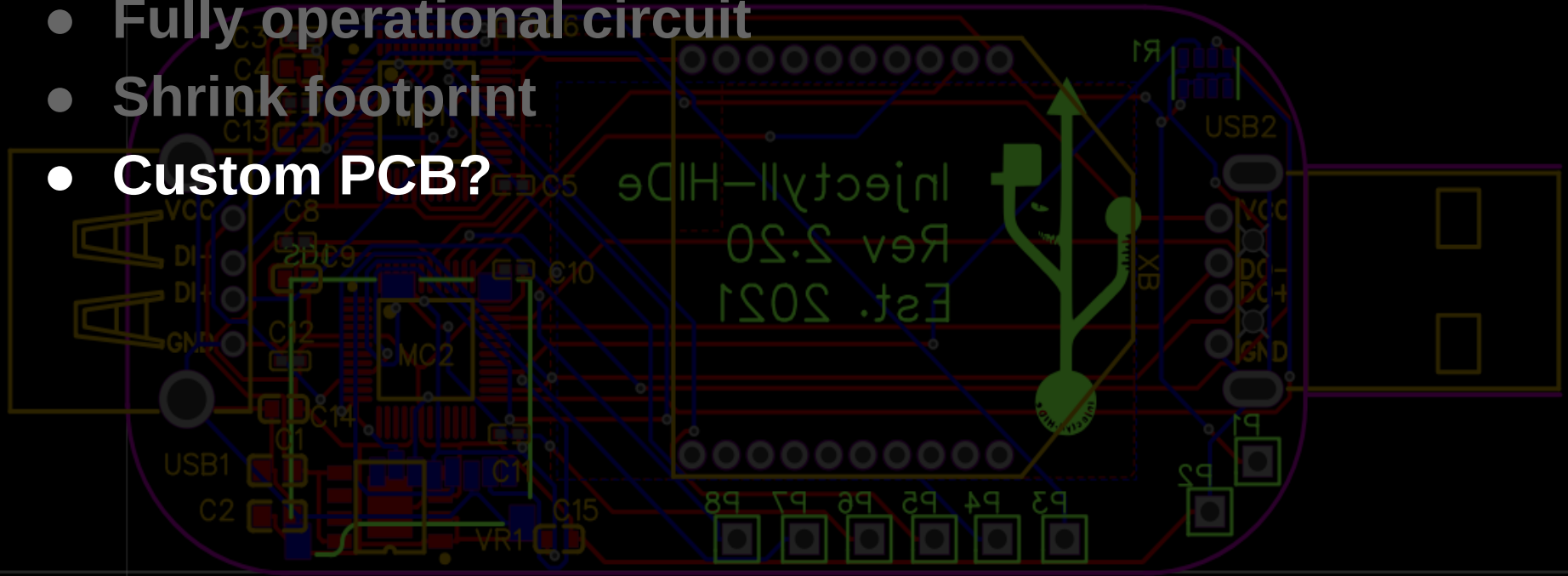
Prototype #3 Conclusions

- Fully operational circuit
- **Shrink footprint**

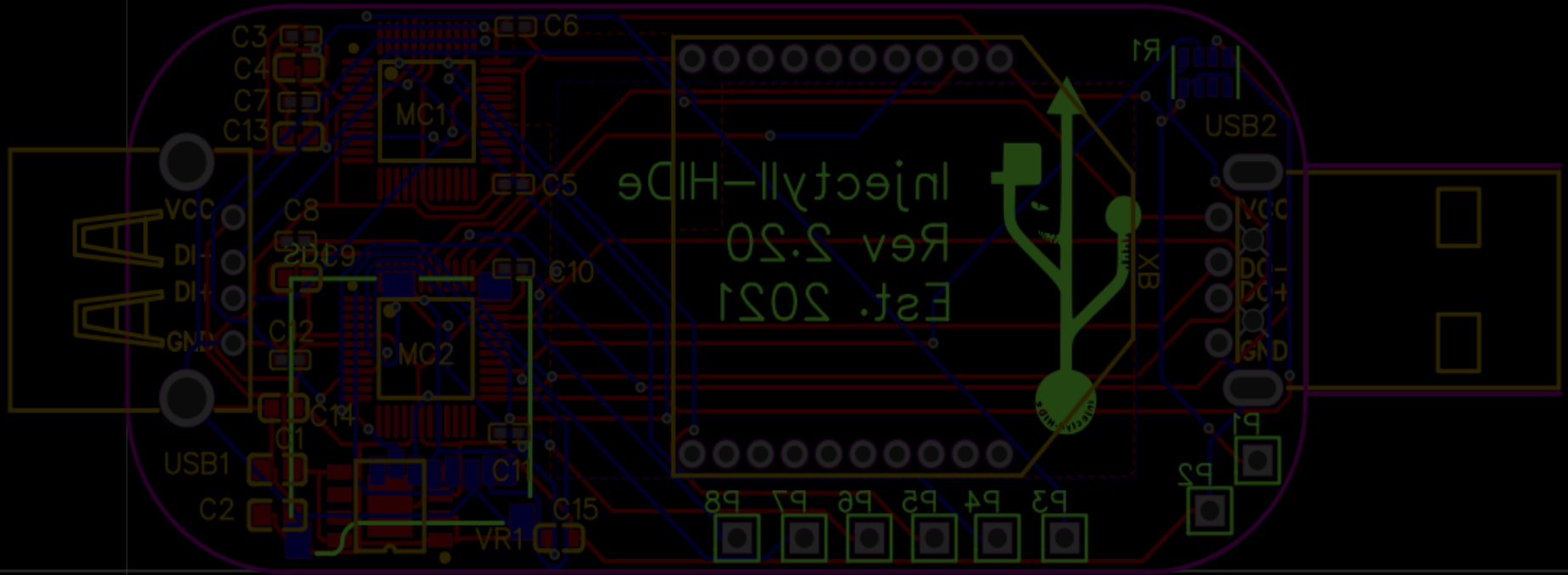


Prototype #3 Conclusions

- Fully operational circuit
- Shrink footprint
- **Custom PCB?**



Prototype #4



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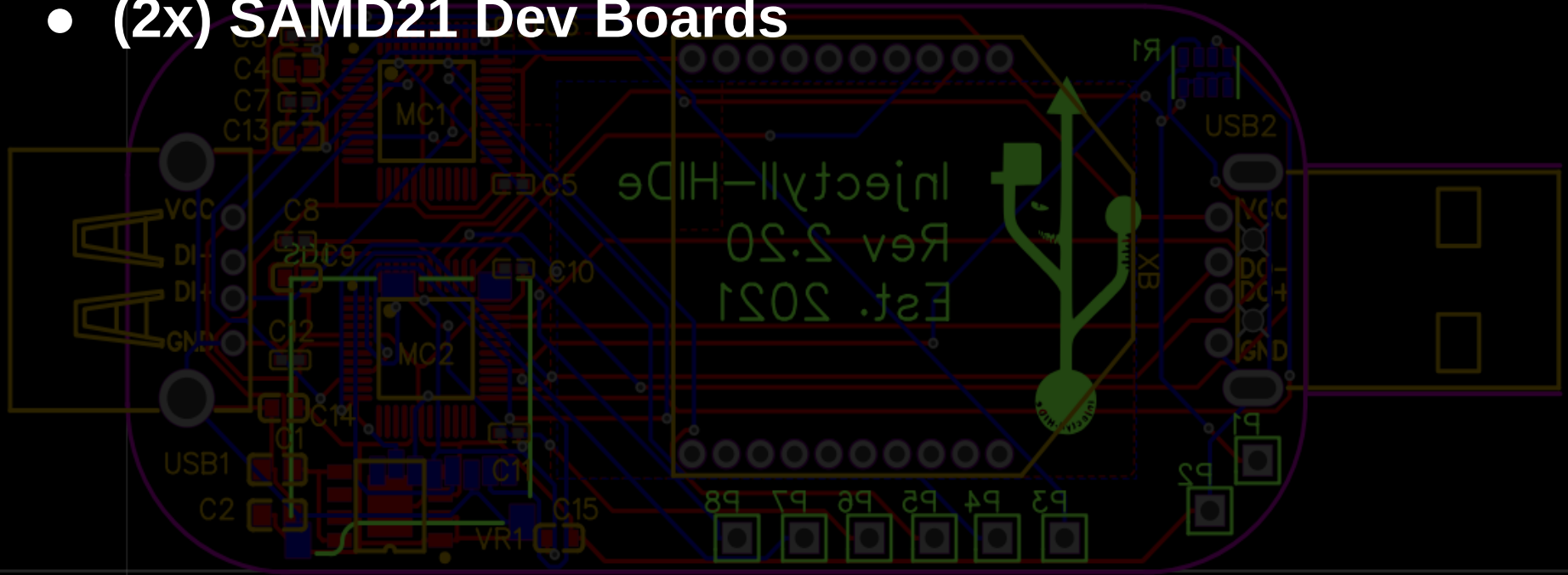
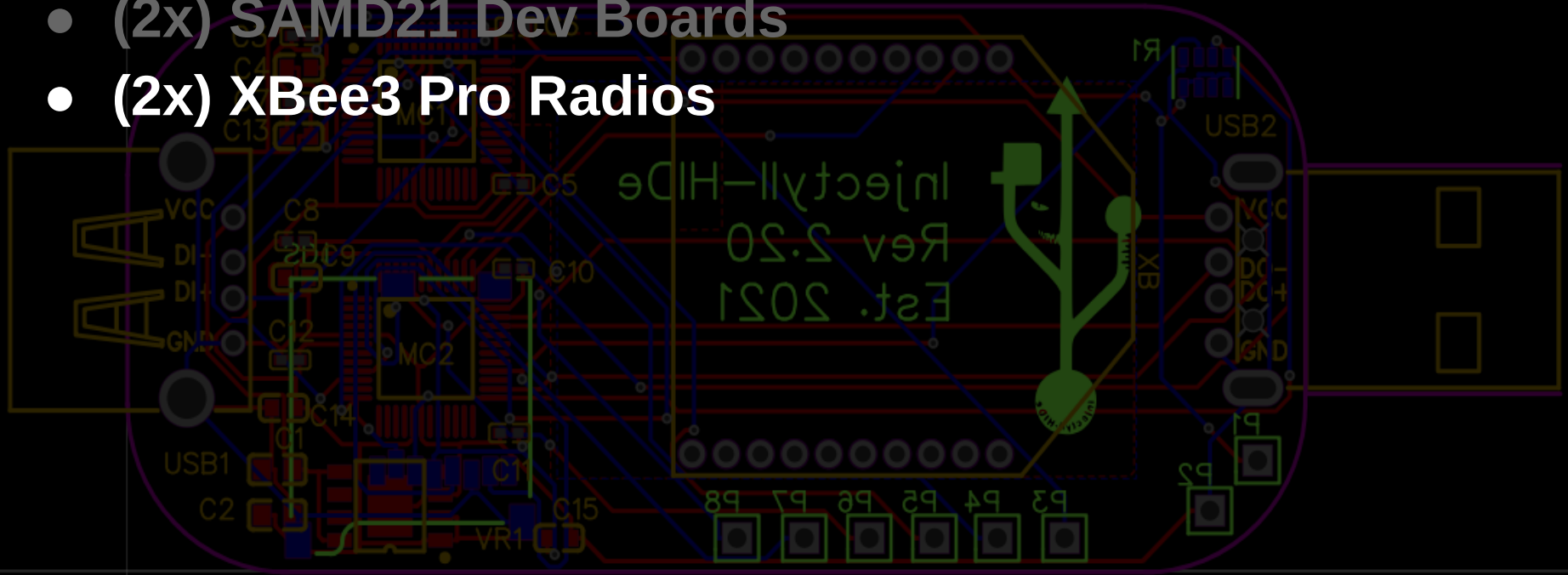
Prototype #4

- **(2x) SAMD21 Dev Boards**



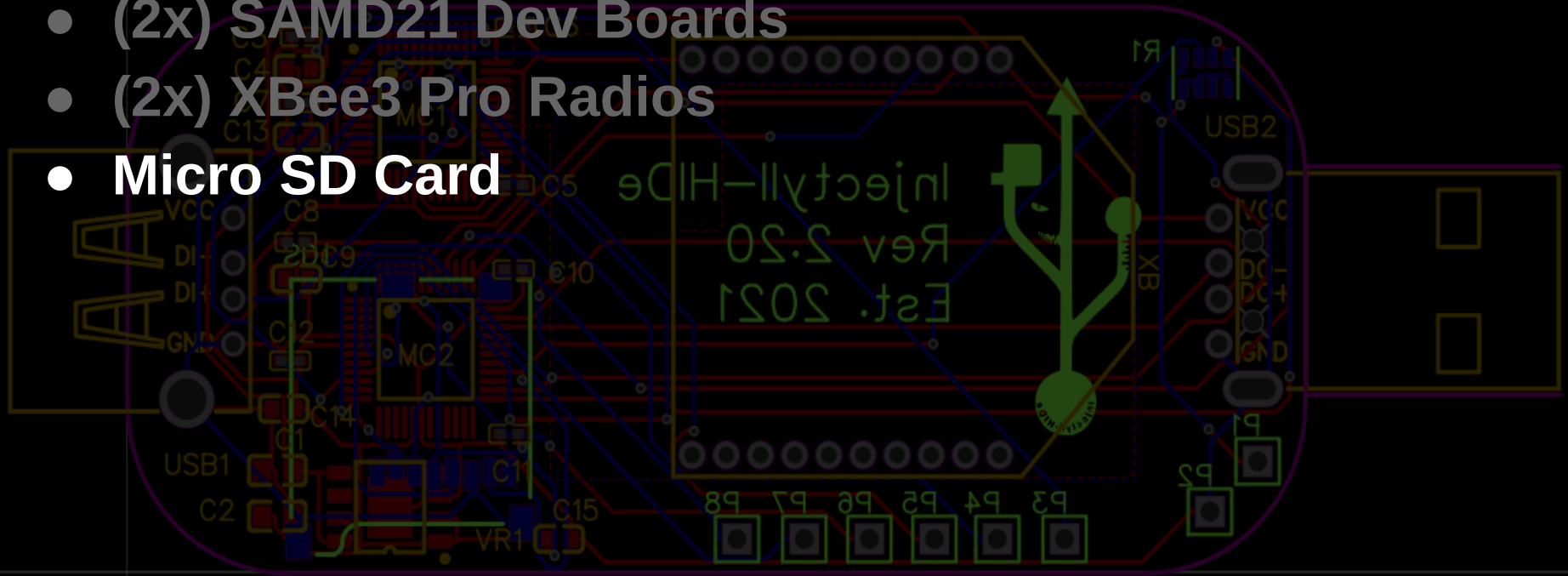
Prototype #4

- (2x) SAMD21 Dev Boards
- **(2x) XBee3 Pro Radios**

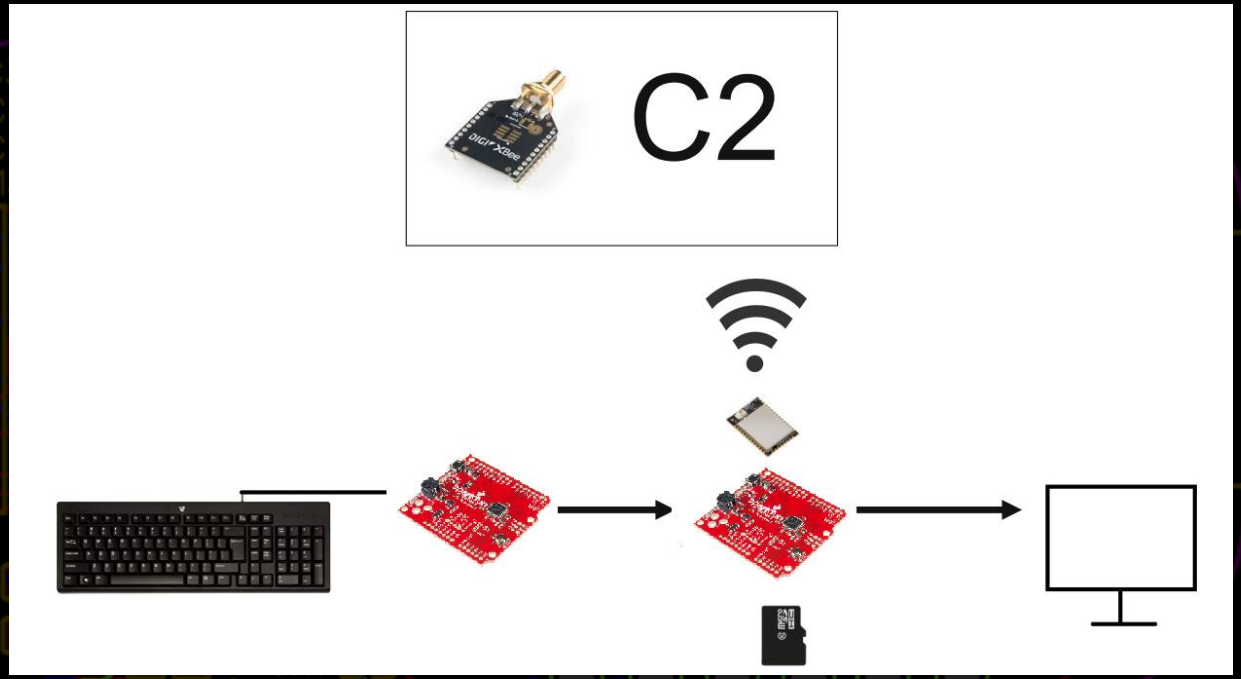


Prototype #4

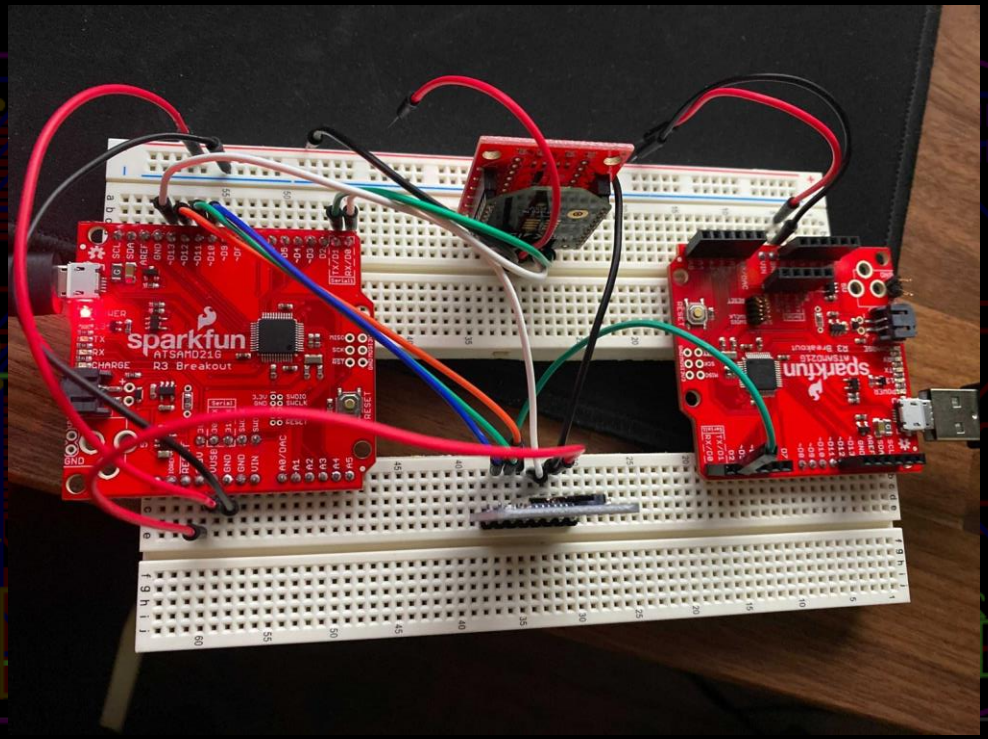
- (2x) SAMD21 Dev Boards
- (2x) XBee3 Pro Radios
- **Micro SD Card**



Prototype #4 Layout



Prototype #4



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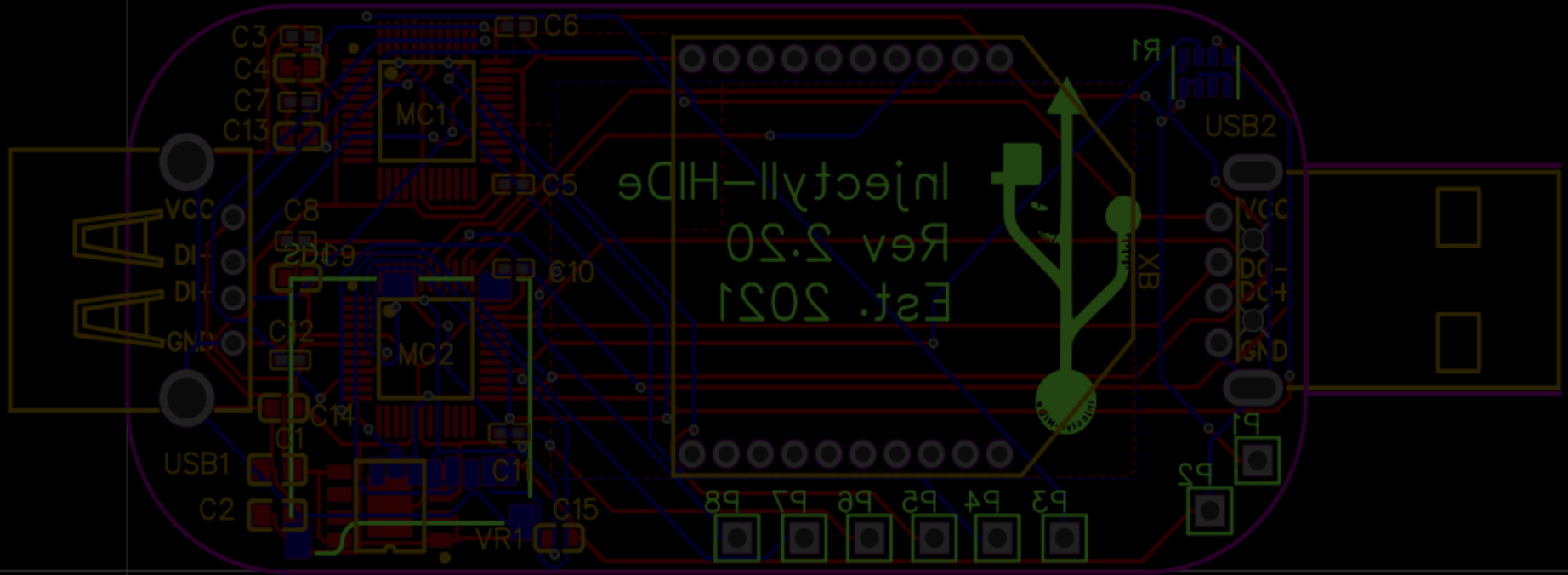
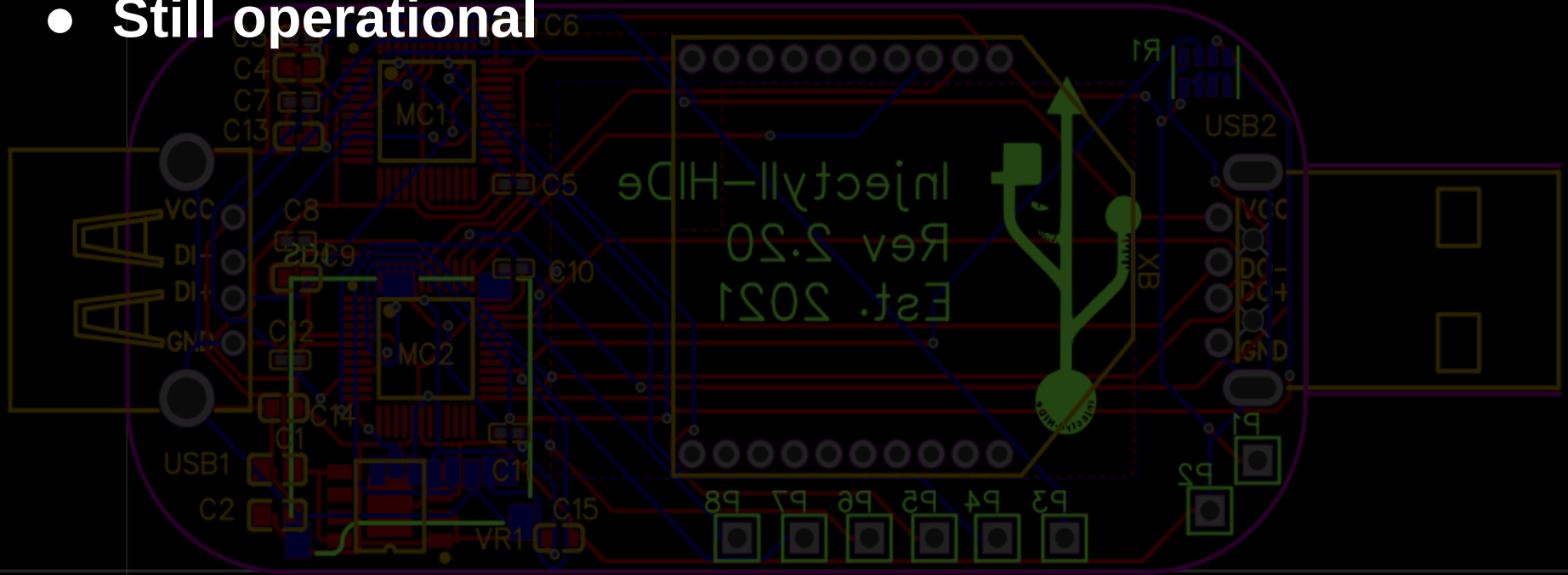
Prototype #4 Conclusions



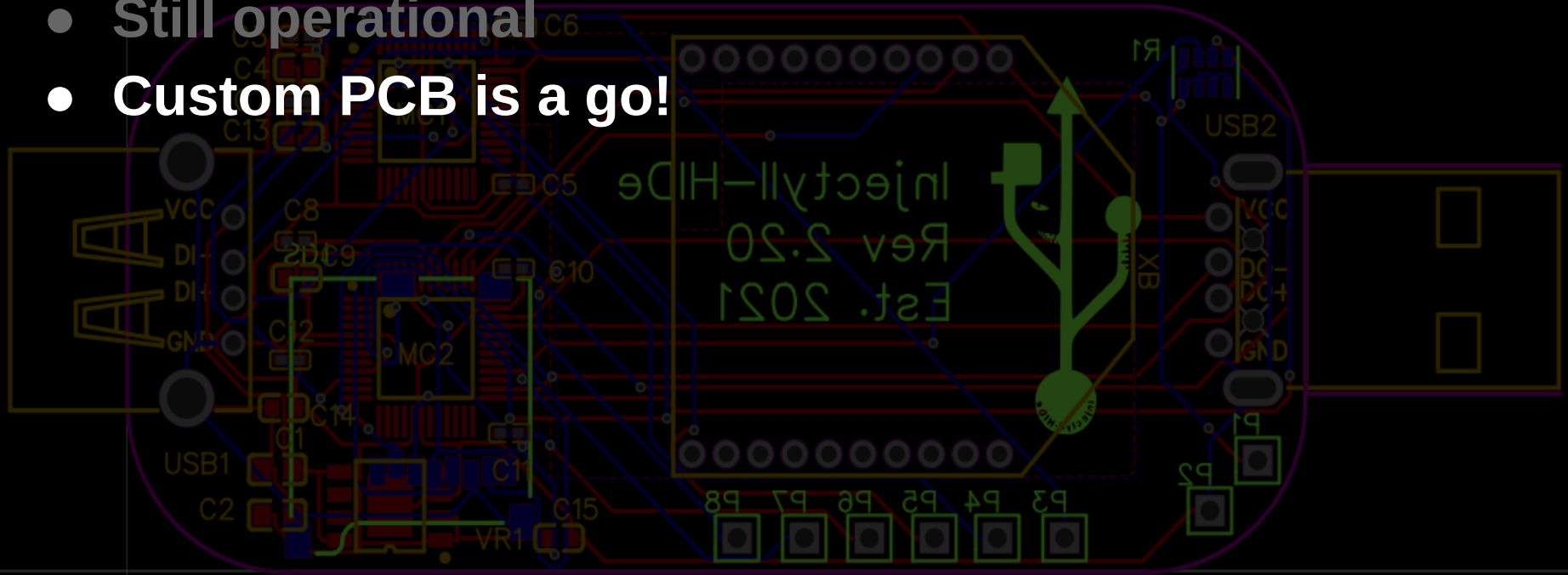
Prototype #4 Conclusions

- **Still operational**

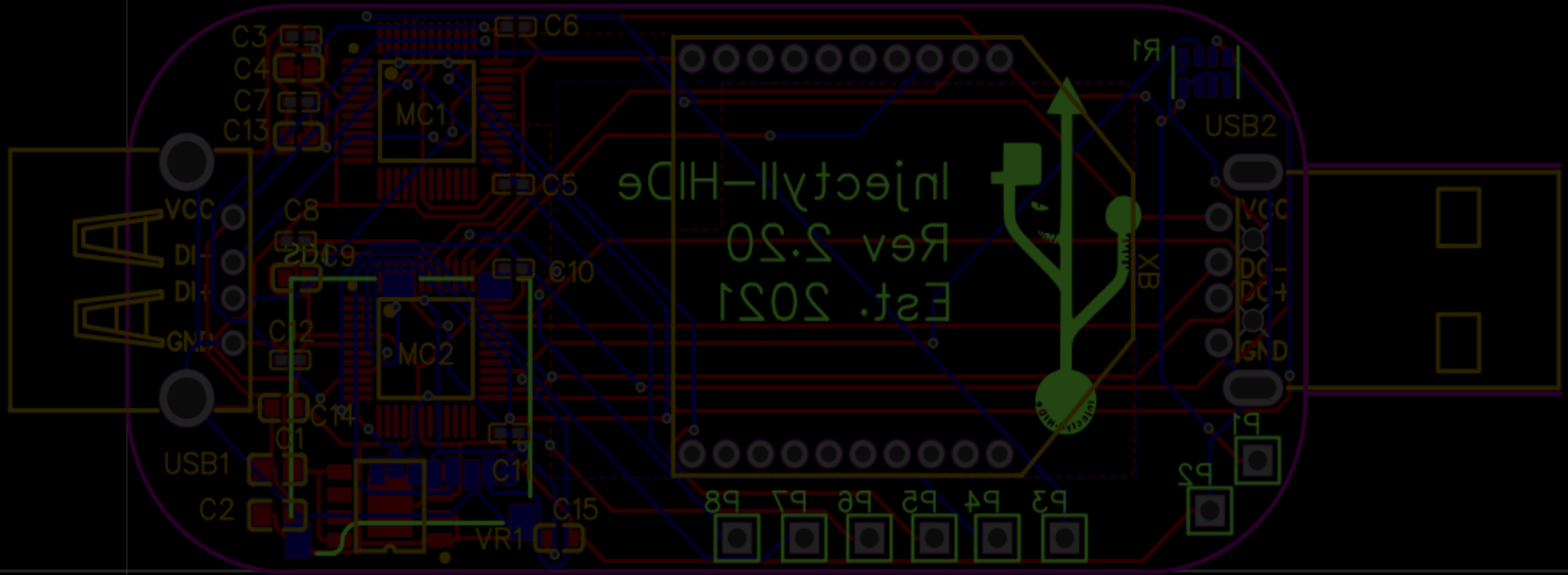


Prototype #4 Conclusions

- Still operational
- **Custom PCB is a go!**



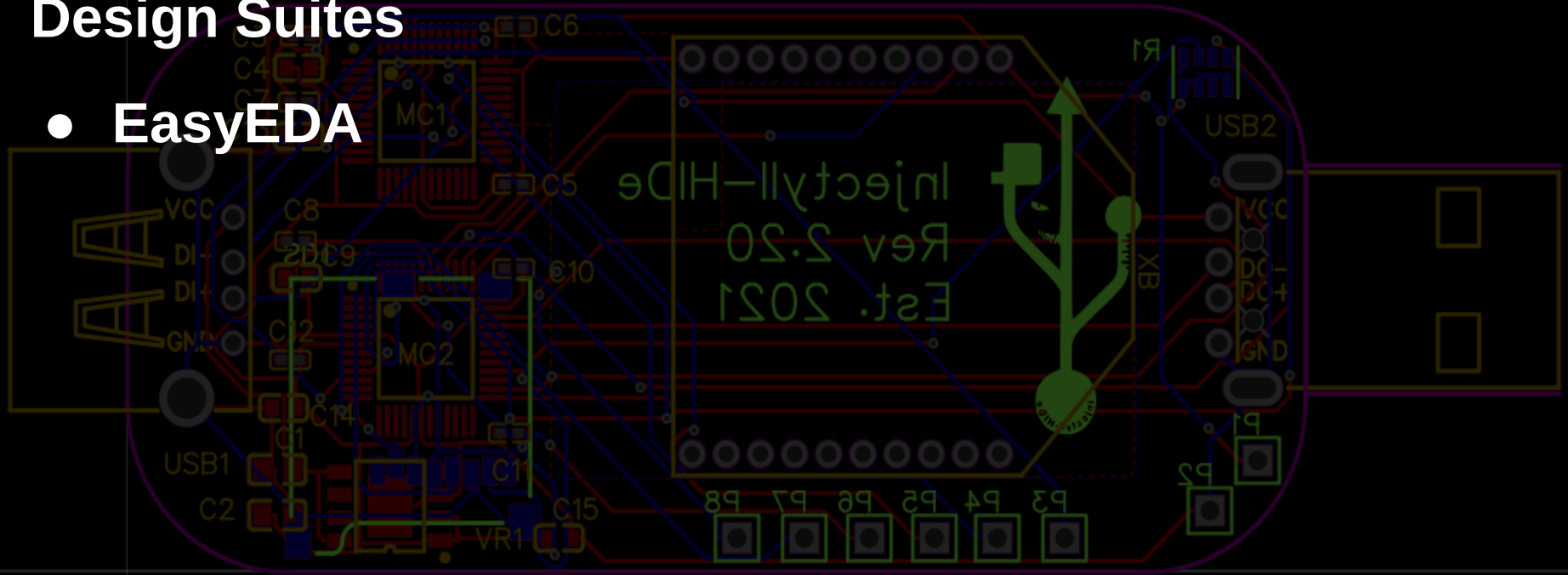
Custom PCB


C3
C4
C7
C13
C6
MC1
C5
C8
C9
C10
MC2
C12
C14
C1
C11
C15
VR1
USB1
C2
VCC
DI-
DI+
GND
P8 P7 P6 P5 P4 P3
R1
USB2
P1
P2
Injectyll-HIDe
Rev 2.20
Est. 2021

Custom PCB

Design Suites

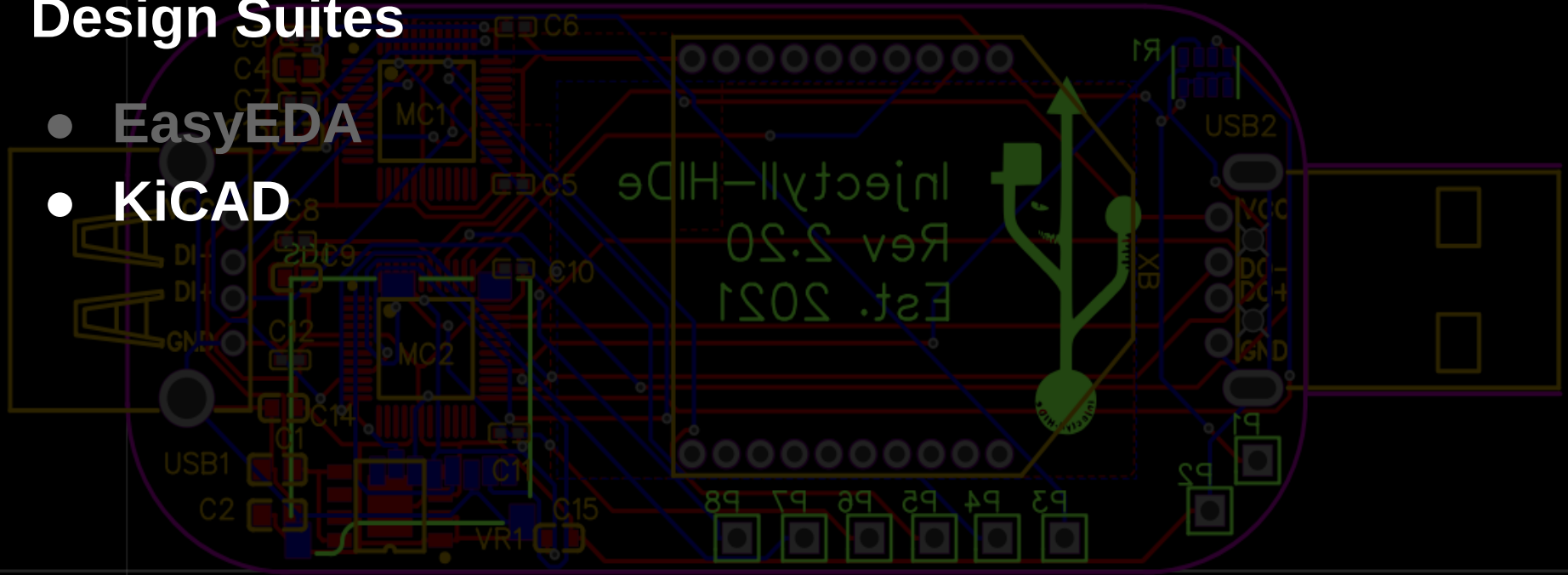
- EasyEDA



Custom PCB

Design Suites

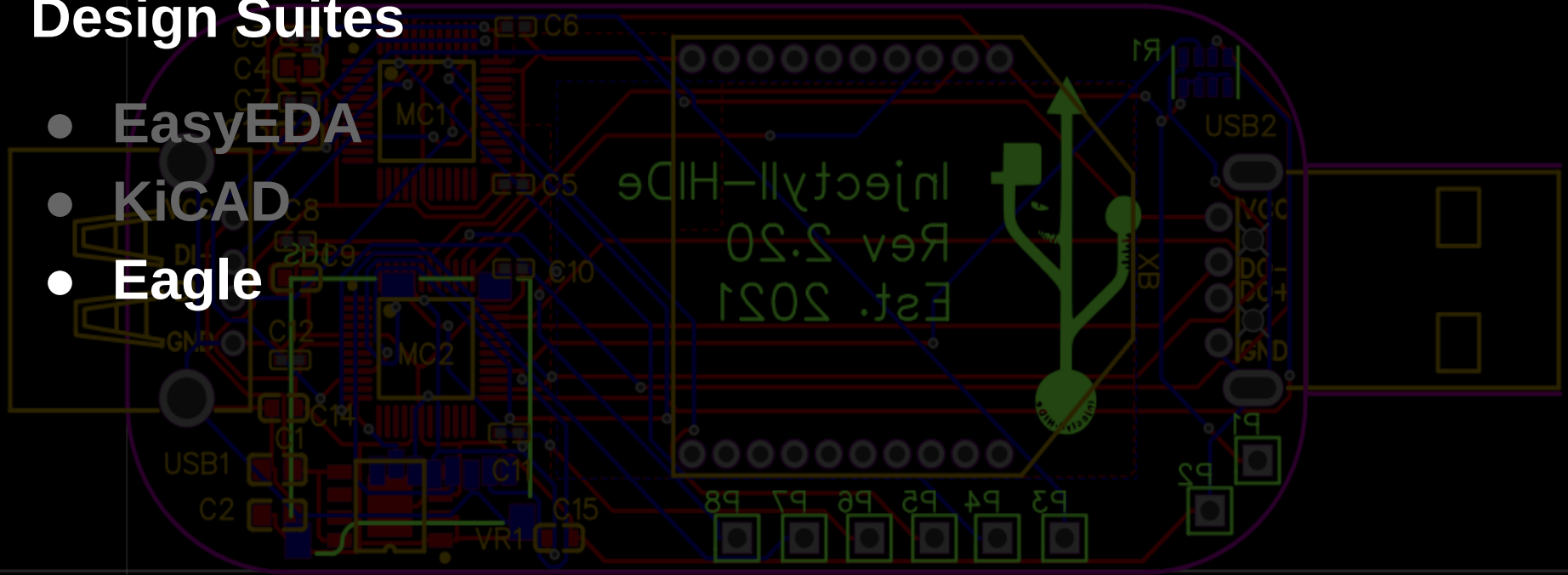
- EasyEDA
- KiCAD



Custom PCB

Design Suites

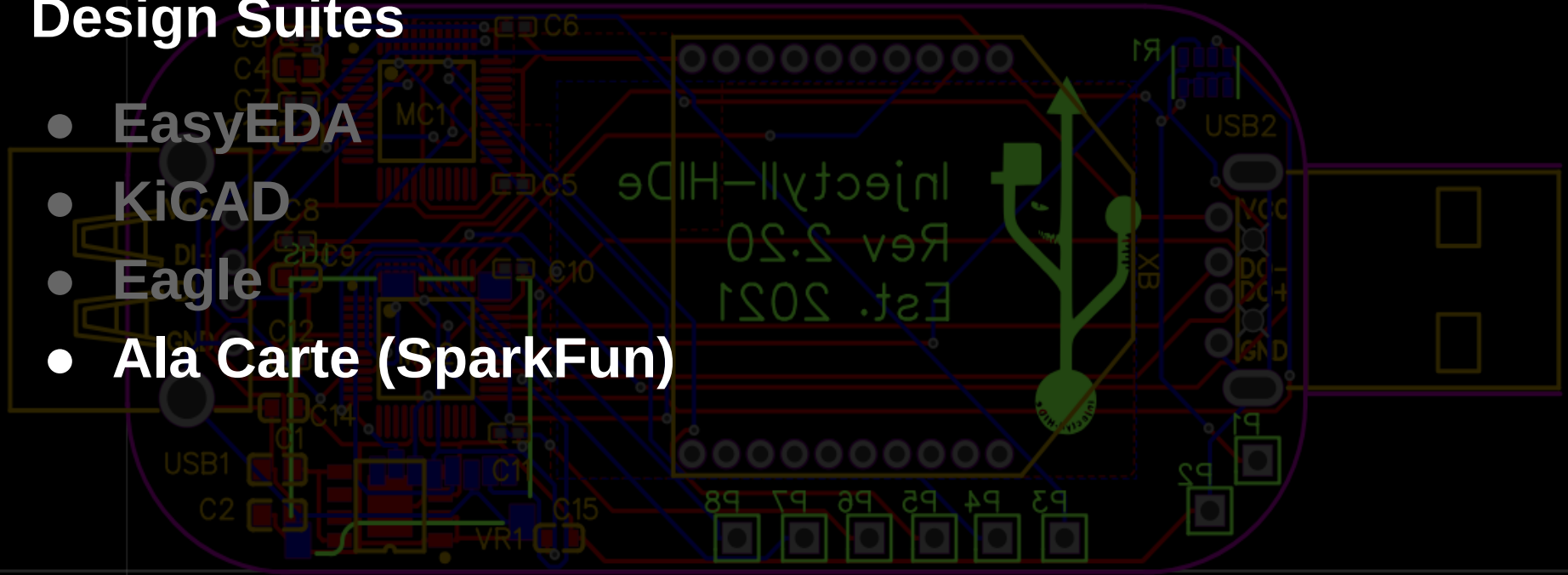
- EasyEDA
- KiCAD
- **Eagle**



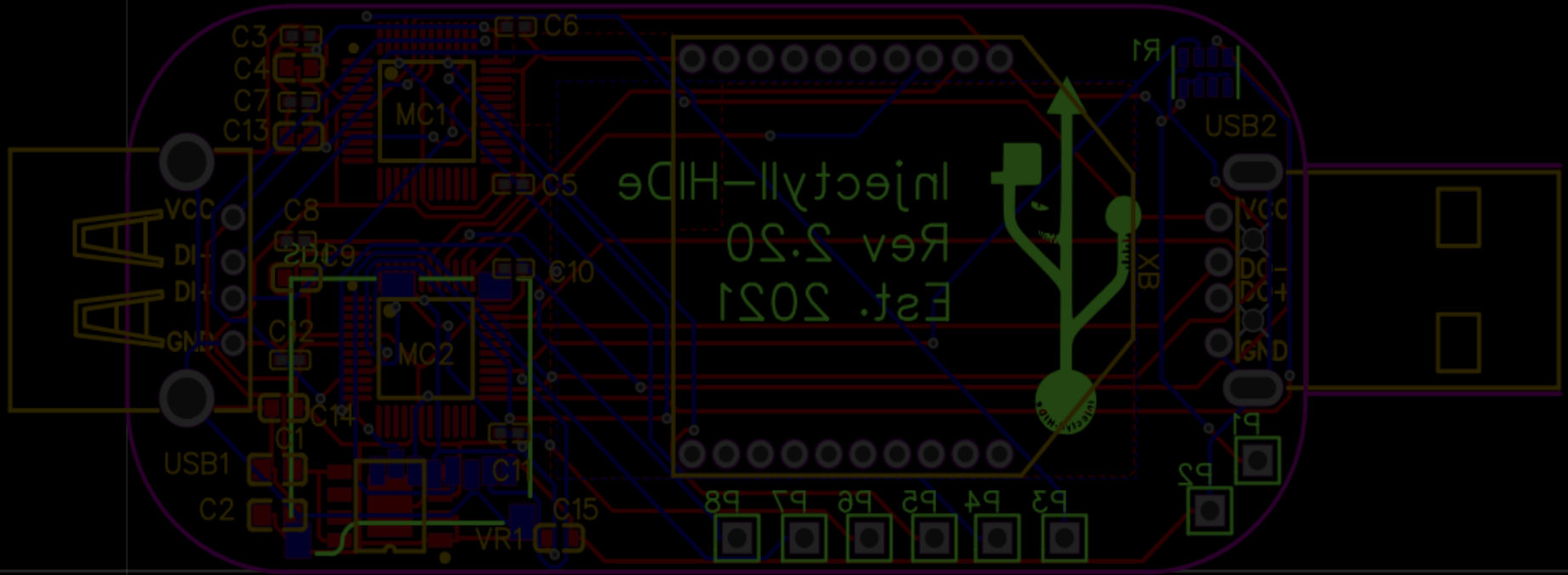
Custom PCB

Design Suites

- EasyEDA
- KiCAD
- Eagle
- **Ala Carte (SparkFun)**

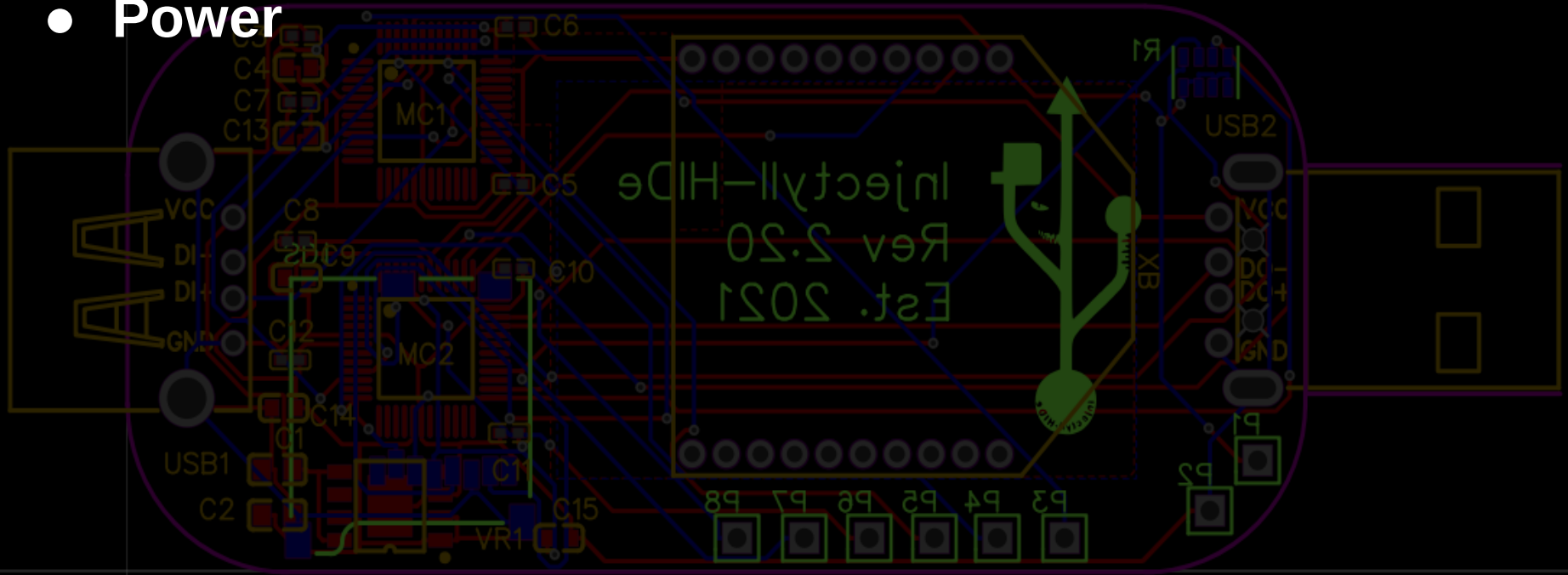


PCB Design Considerations



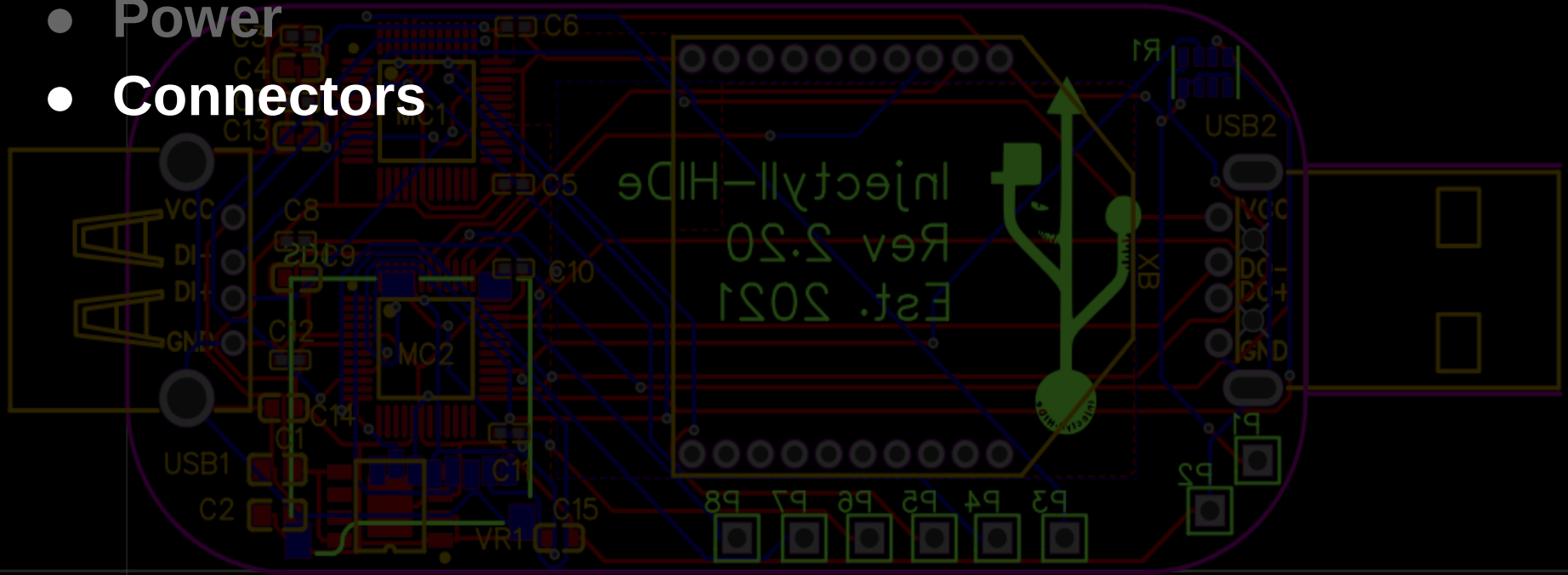
PCB Design Considerations

- Power



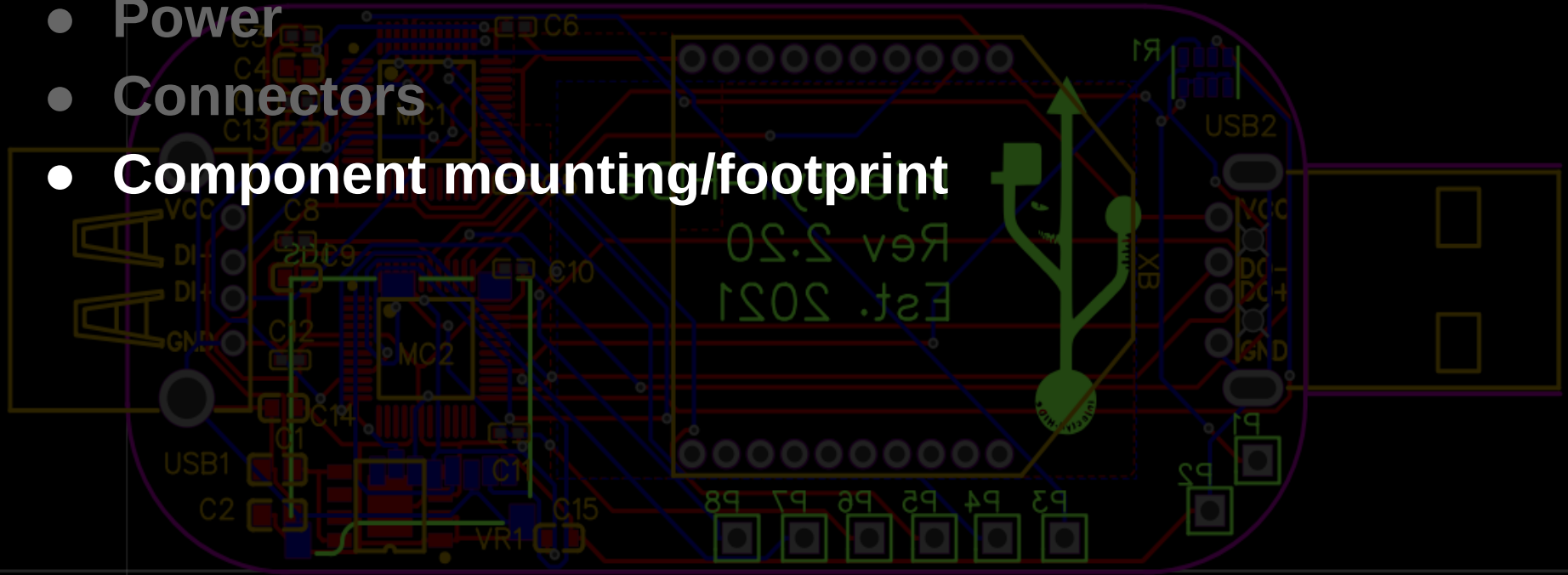
PCB Design Considerations

- Power
- Connectors



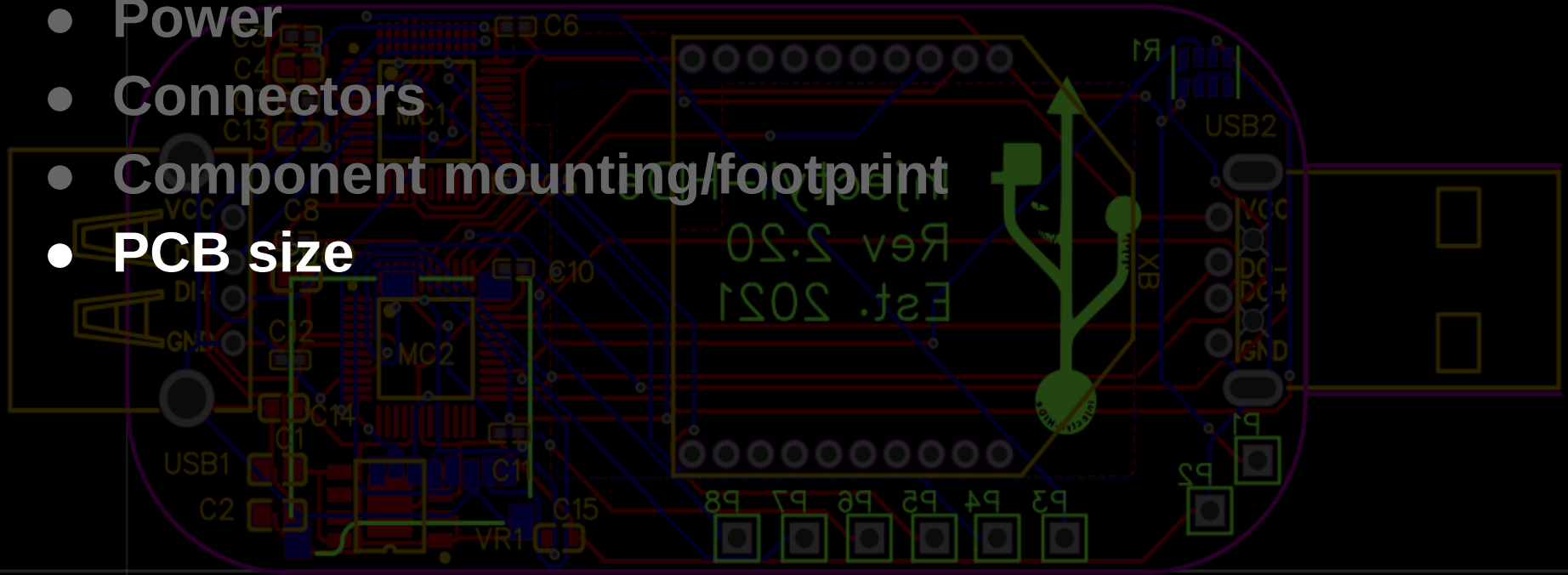
PCB Design Considerations

- Power
- Connectors
- **Component mounting/footprint**



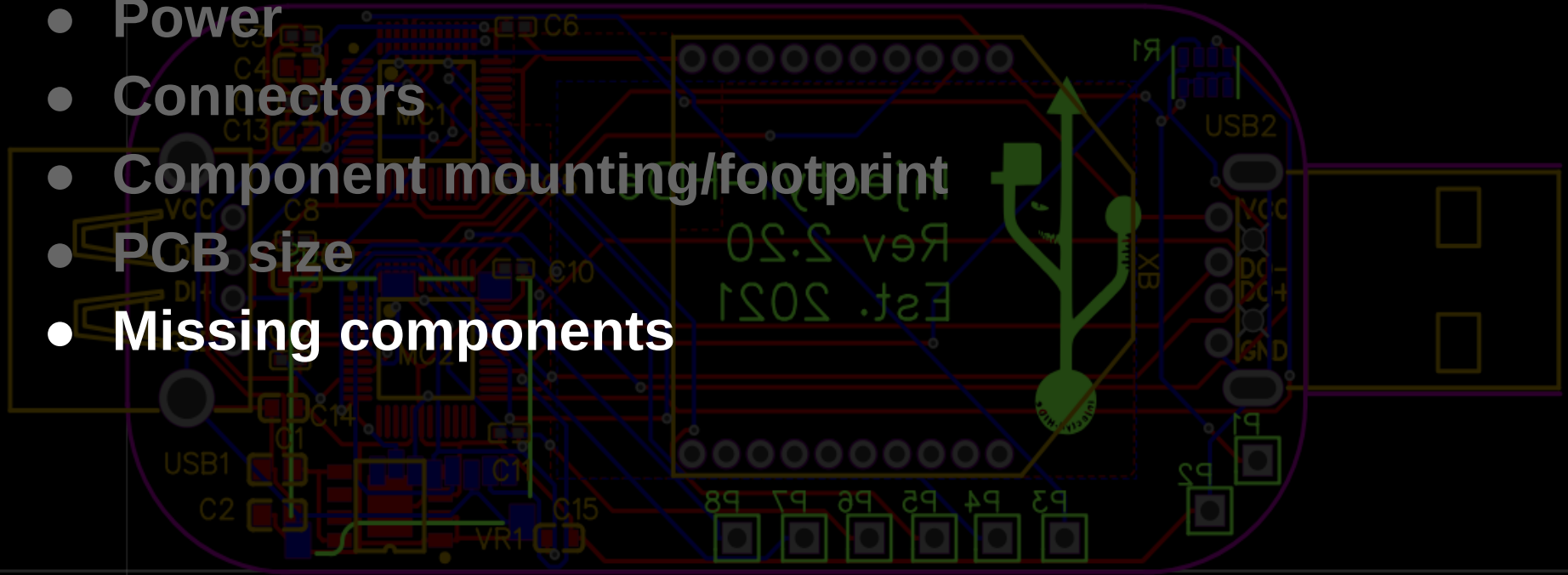
PCB Design Considerations

- Power
- Connectors
- Component mounting/footprint
- **PCB size**

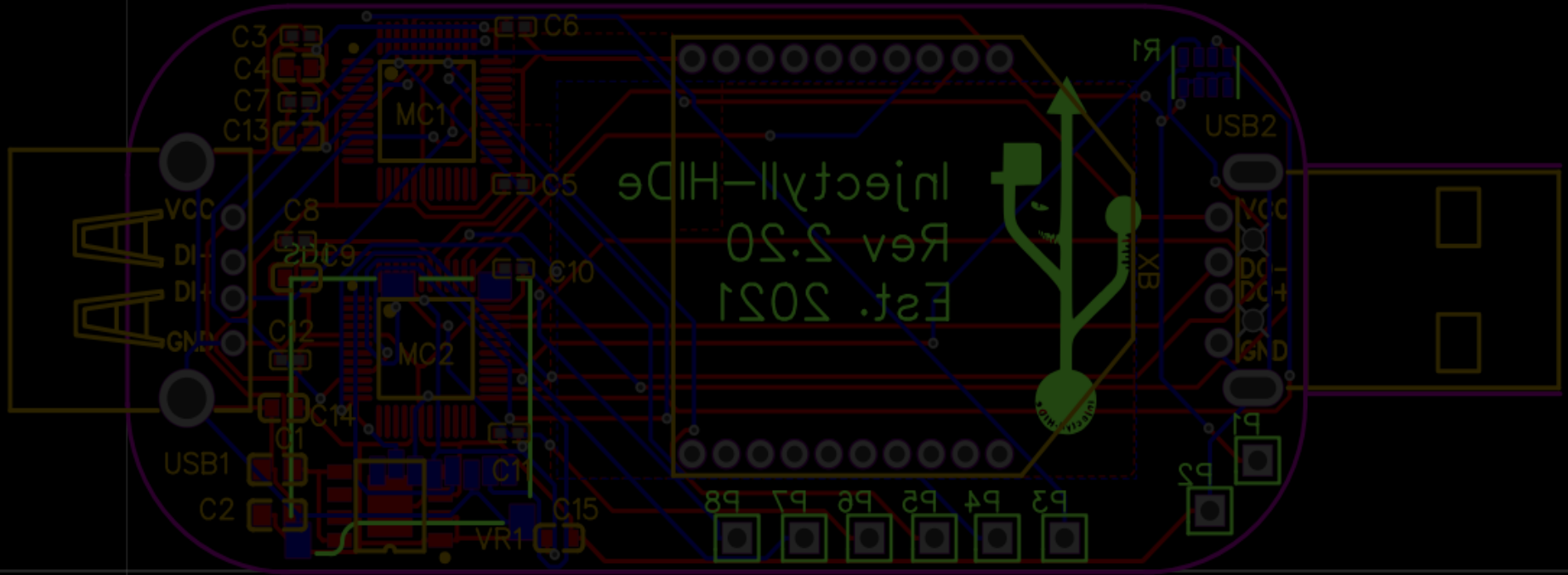


PCB Design Considerations

- Power
- Connectors
- Component mounting/footprint
- PCB size
- **Missing components**



Power



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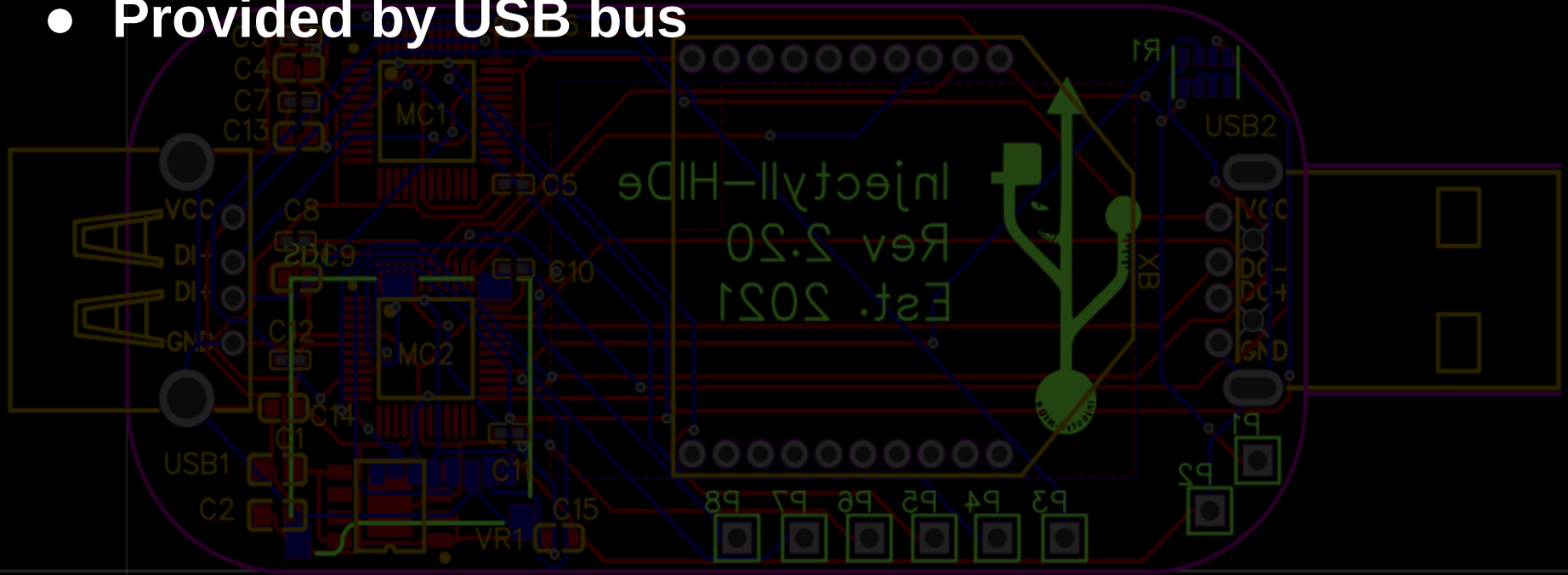
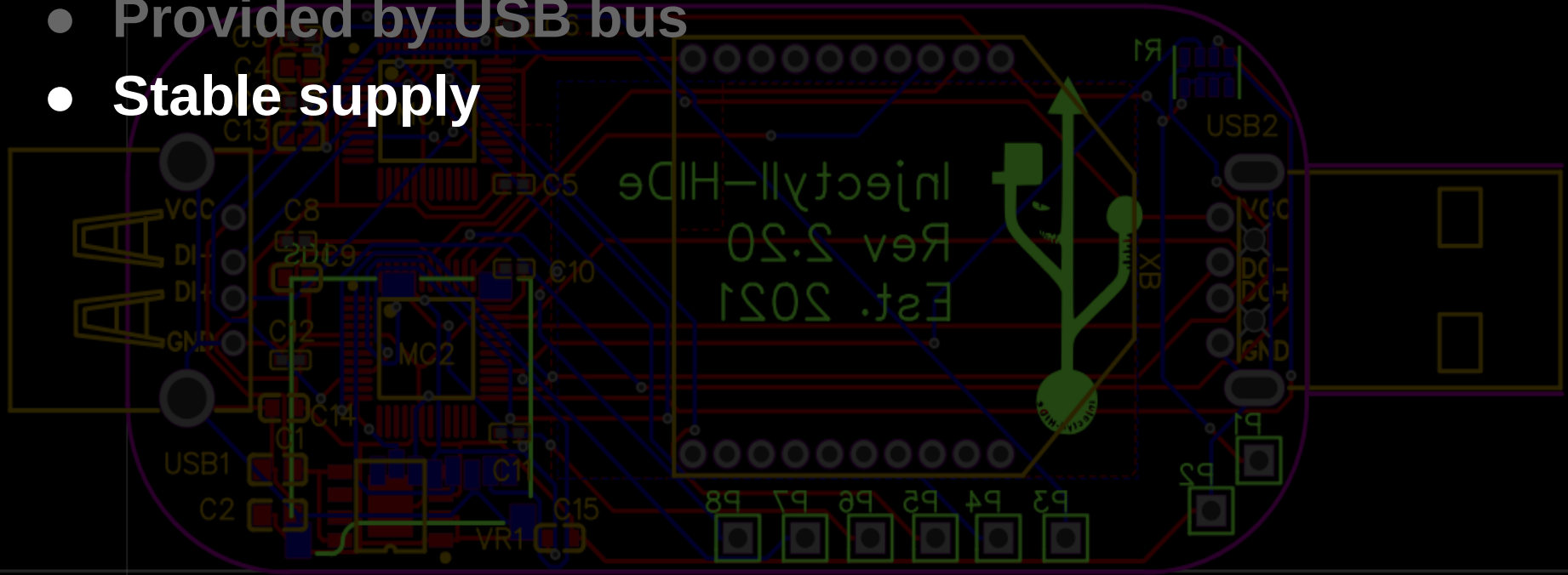
Power

- **Provided by USB bus**



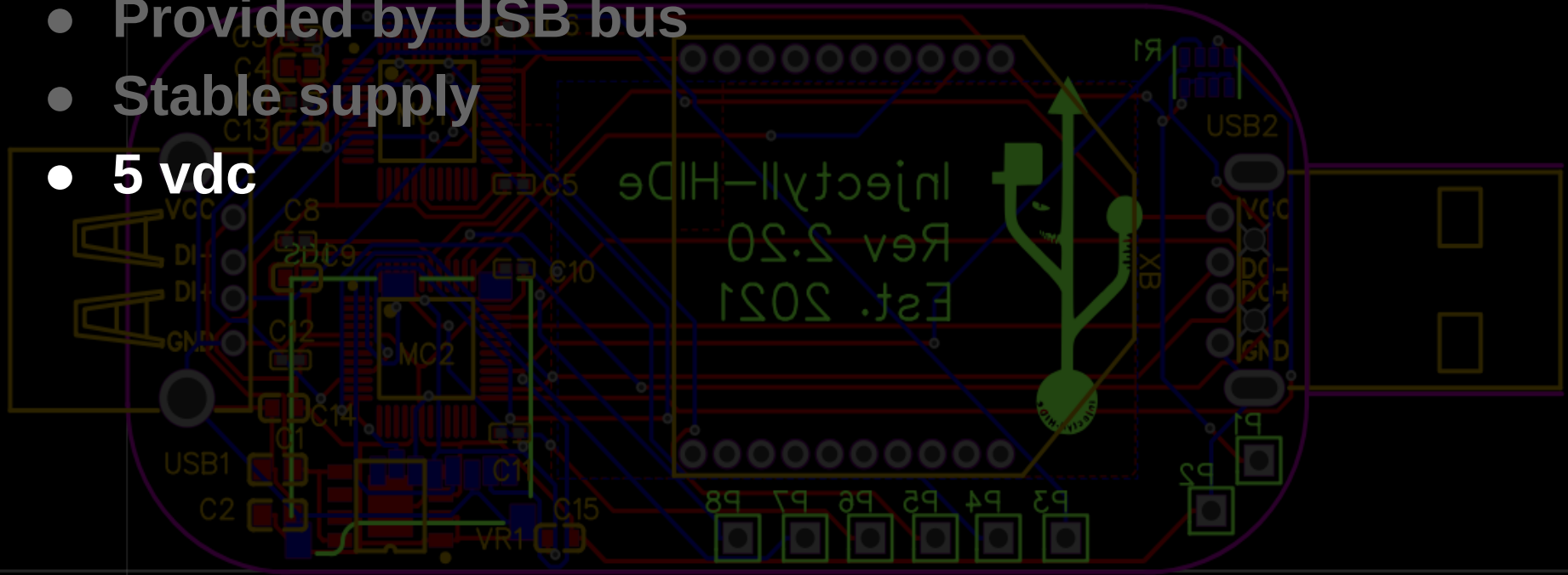
Power

- Provided by USB bus
- **Stable supply**



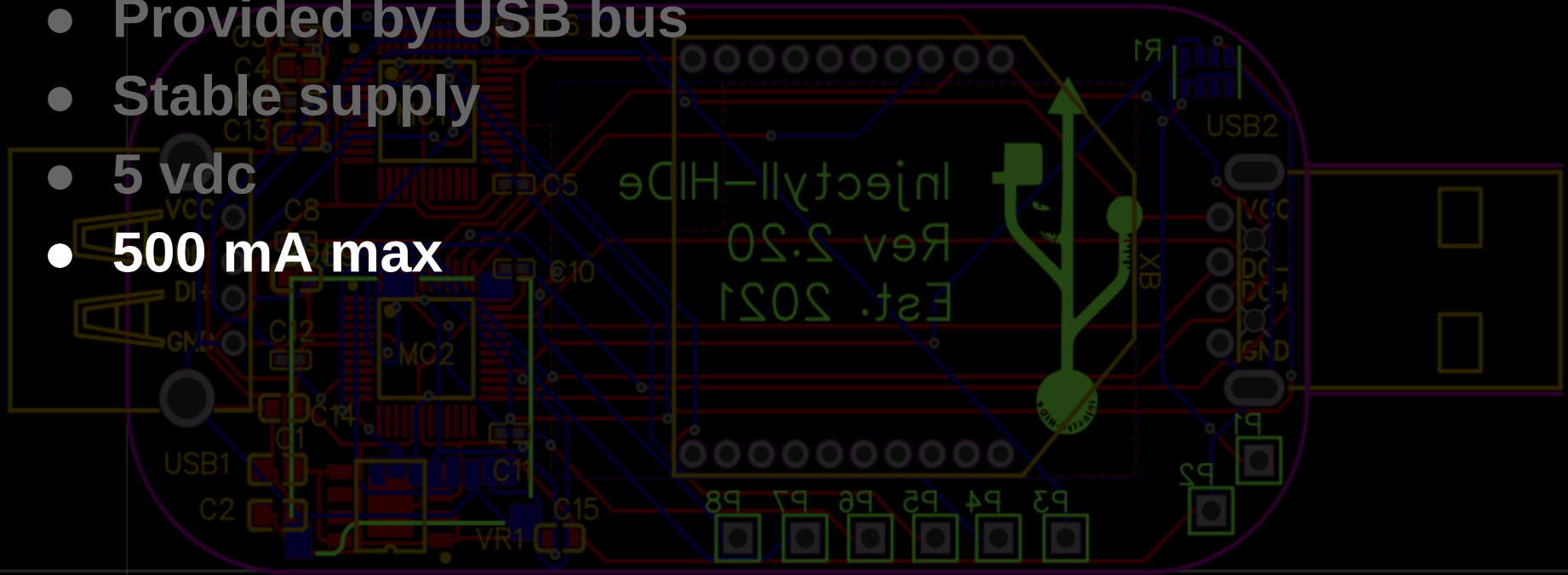
Power

- Provided by USB bus
- Stable supply
- **5 vdc**



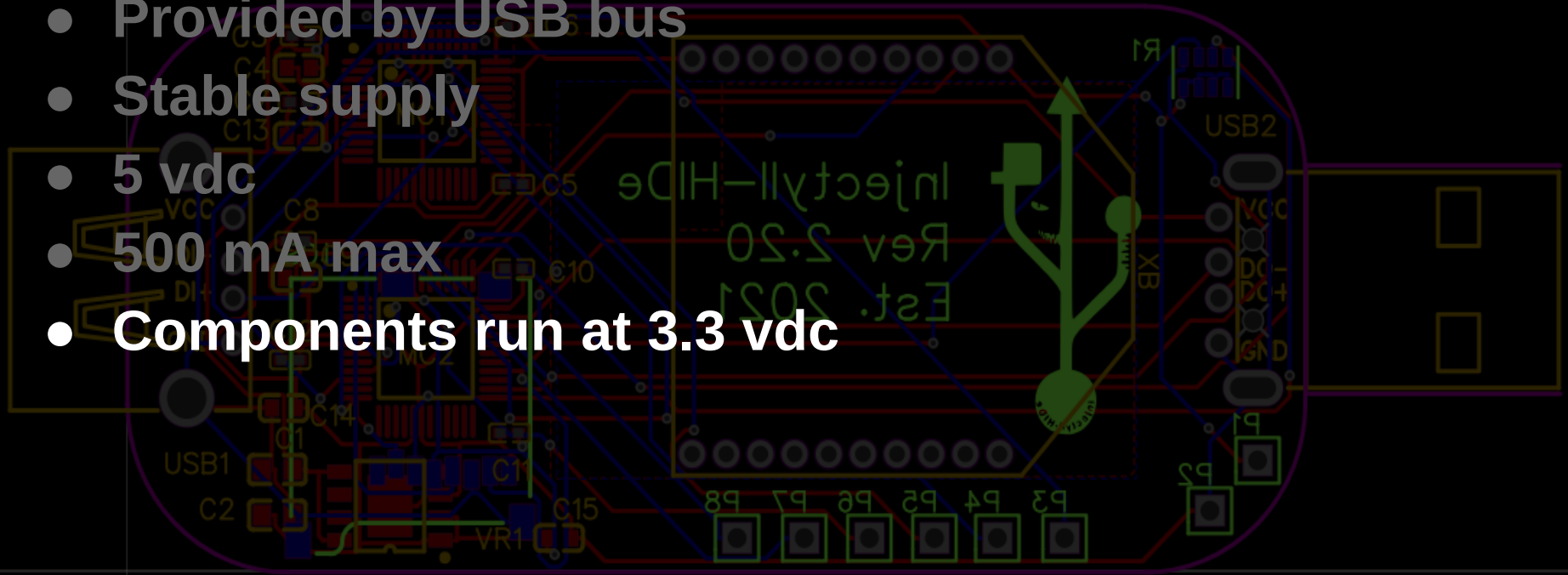
Power

- Provided by USB bus
- Stable supply
- 5 vdc
- **500 mA max**

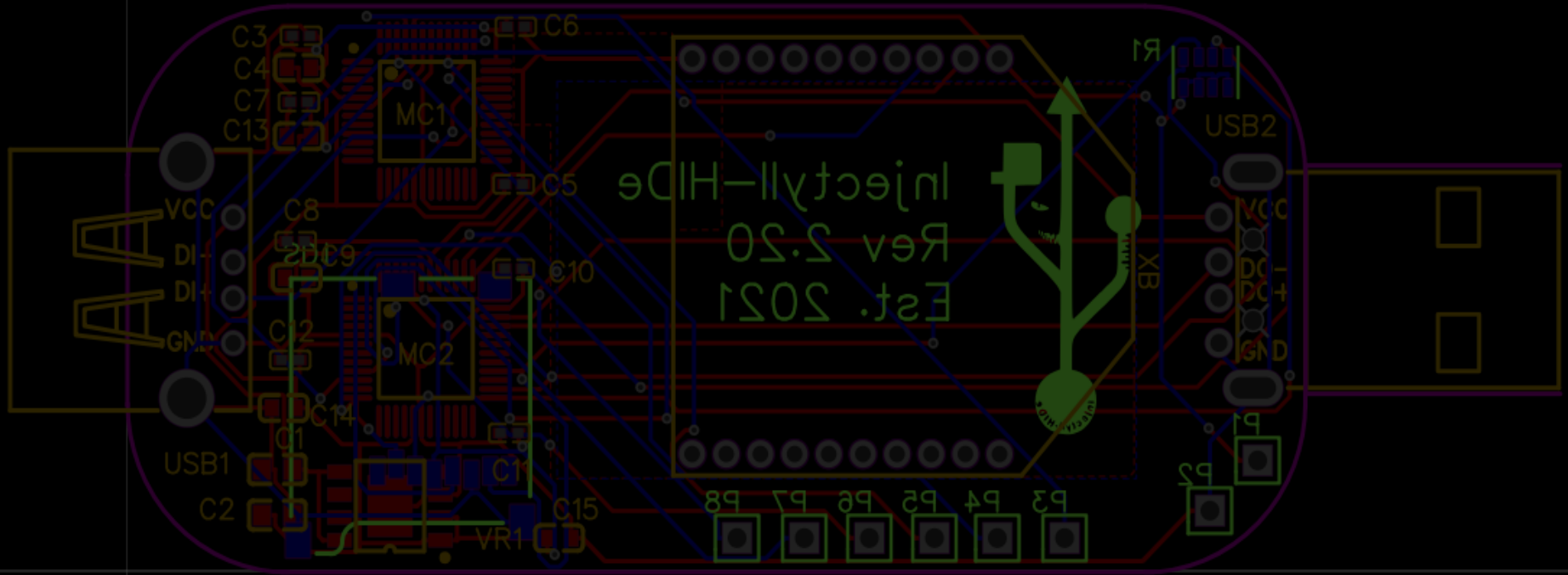


Power

- Provided by USB bus
- Stable supply
- 5 vdc
- 500 mA max
- **Components run at 3.3 vdc**

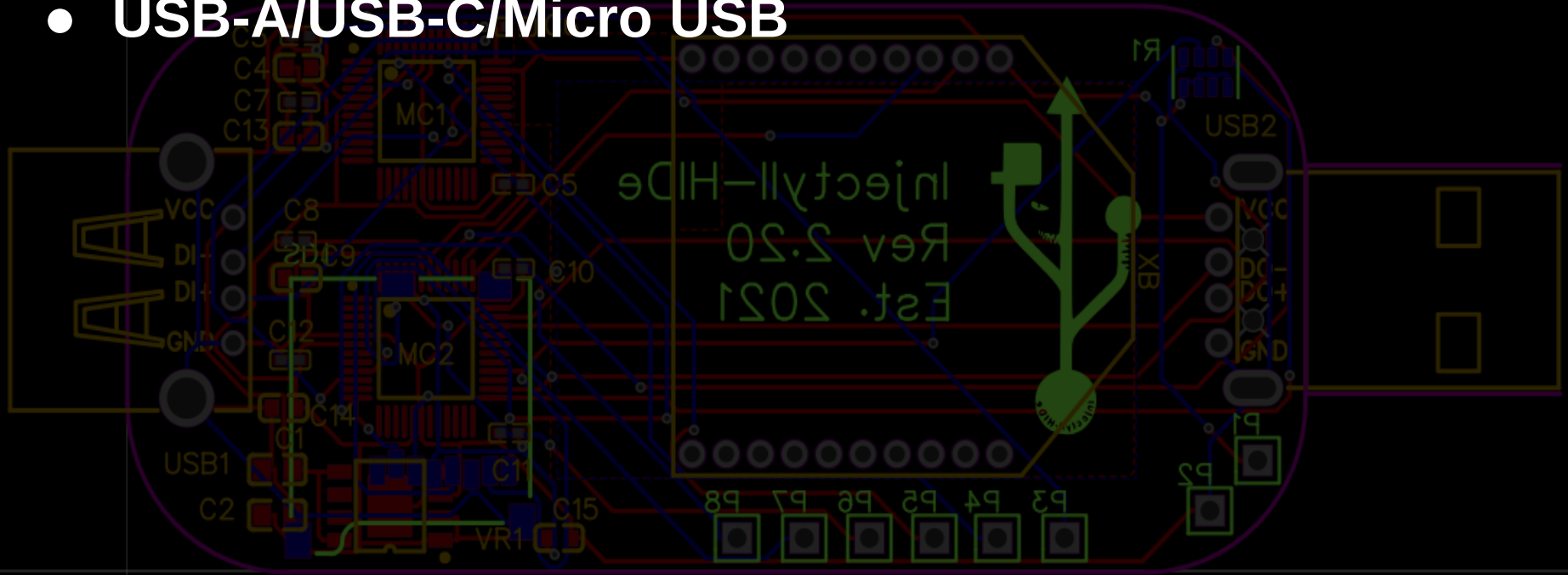


Connectors


C3
C4
C7
C13
C6
MC1
C5
C8
C9
C10
MC2
C12
C14
C1
C11
C15
VR1
USB1
C2
VCC
DI-
DI+
GND
Injectyll-HIDe
Rev 2.20
Est. 2021
R1
USB2
P1
P2
P3
P4
P5
P6
P7
P8

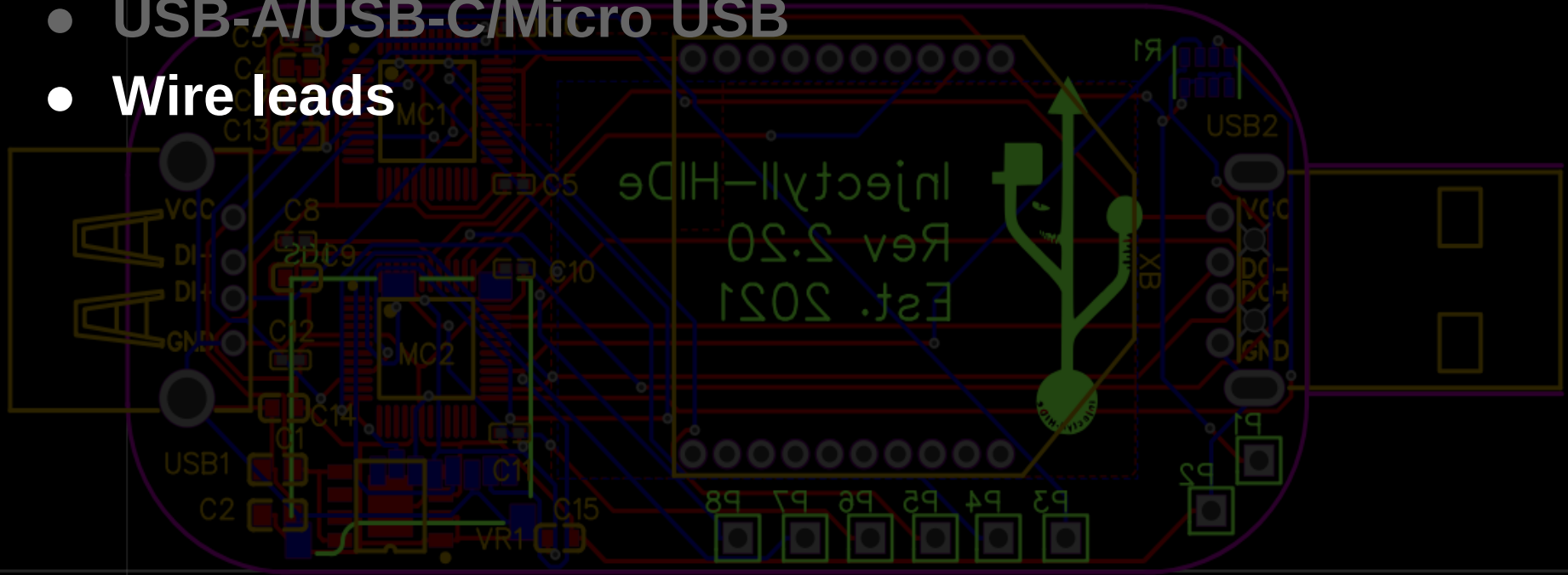
Connectors

- **USB-A/USB-C/Micro USB**



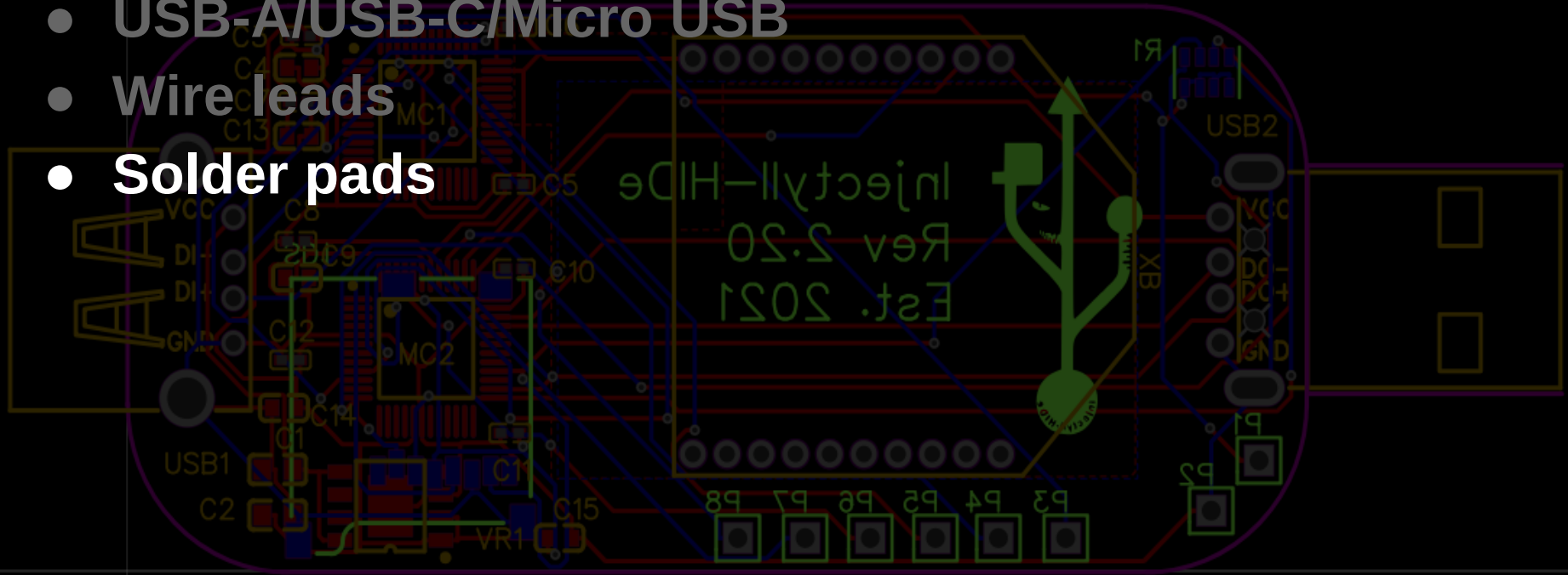
Connectors

- USB-A/USB-C/Micro USB
- **Wire leads**



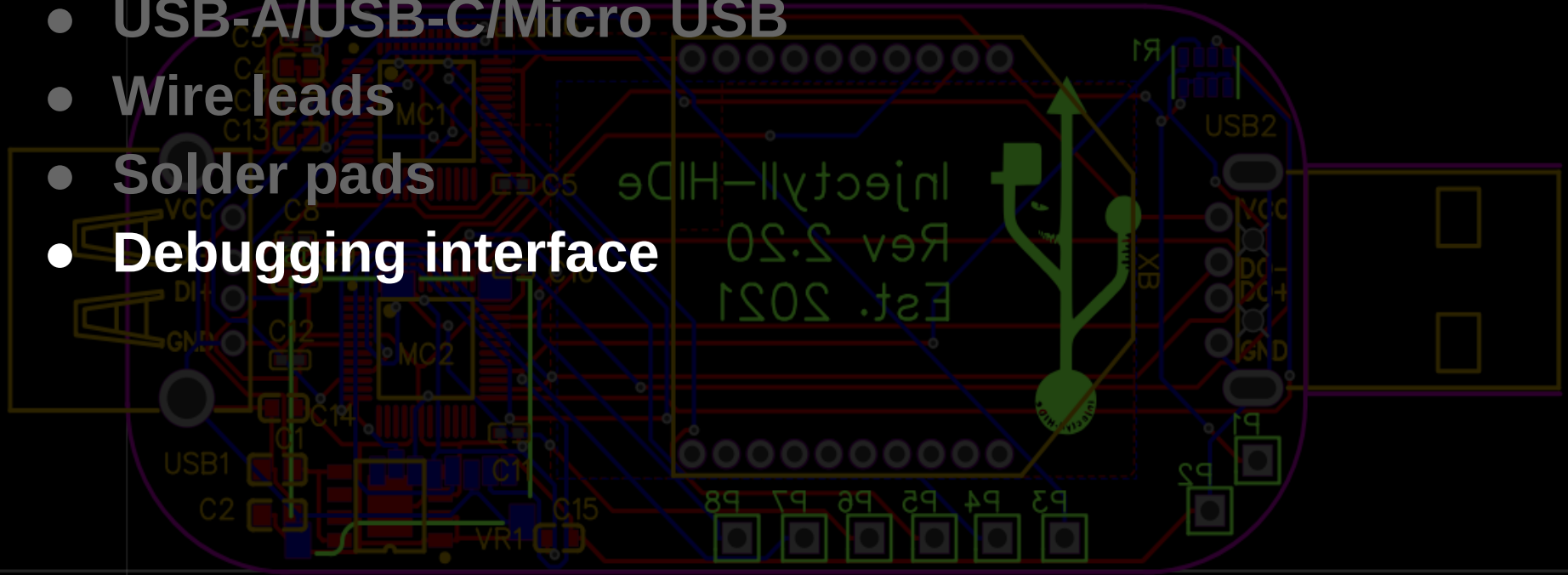
Connectors

- USB-A/USB-C/Micro USB
- Wire leads
- **Solder pads**



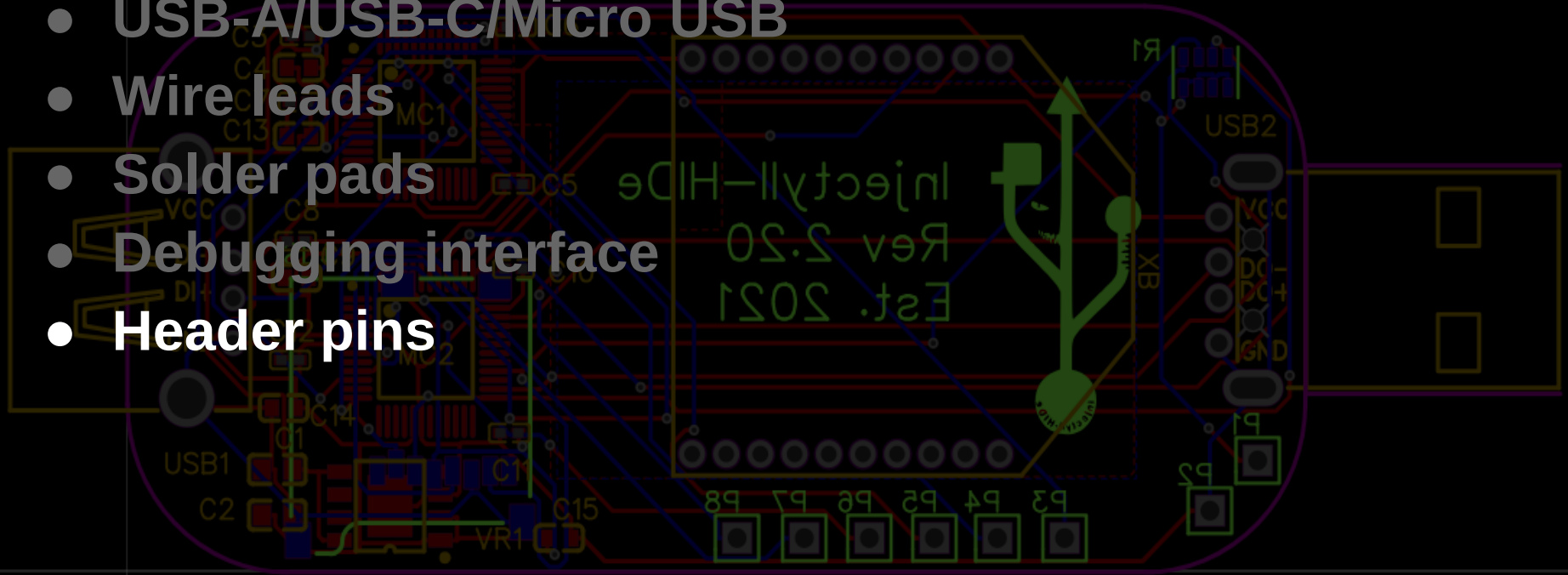
Connectors

- USB-A/USB-C/Micro USB
- Wire leads
- Solder pads
- **Debugging interface**

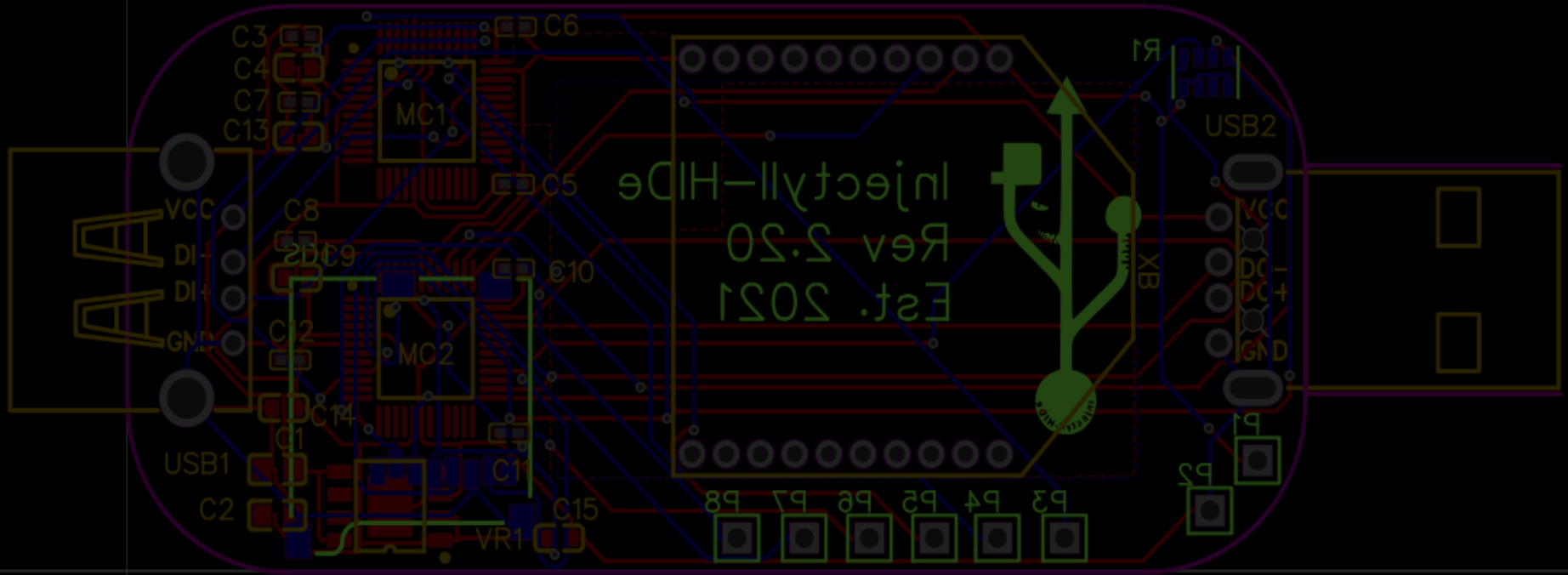


Connectors

- USB-A/USB-C/Micro USB
- Wire leads
- Solder pads
- Debugging interface
- **Header pins**

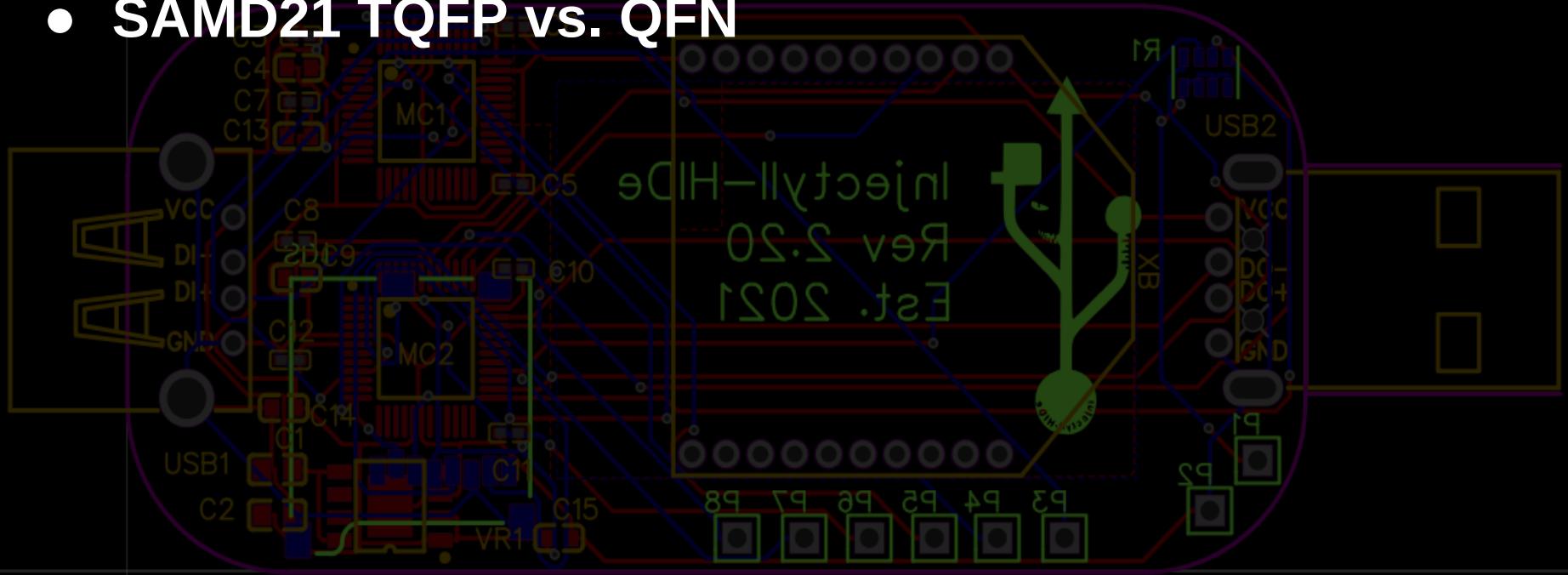


Component Mounting



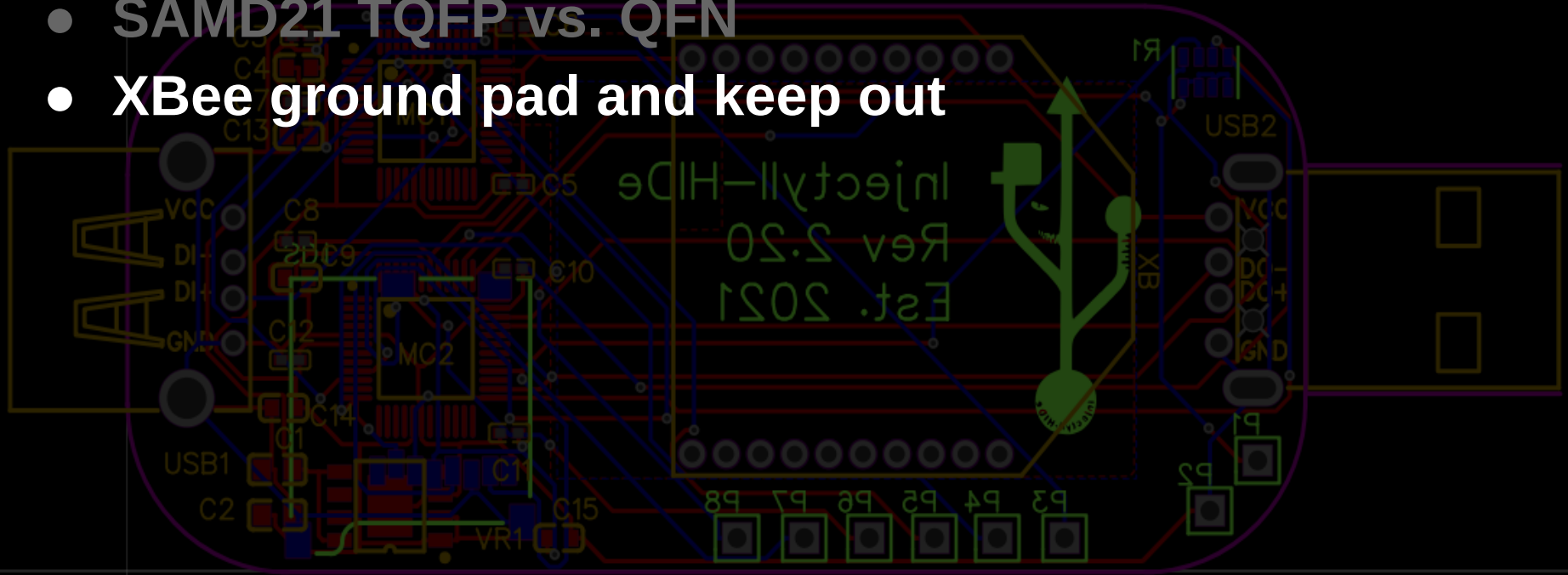
Component Mounting

- **SAMD21 TQFP vs. QFN**



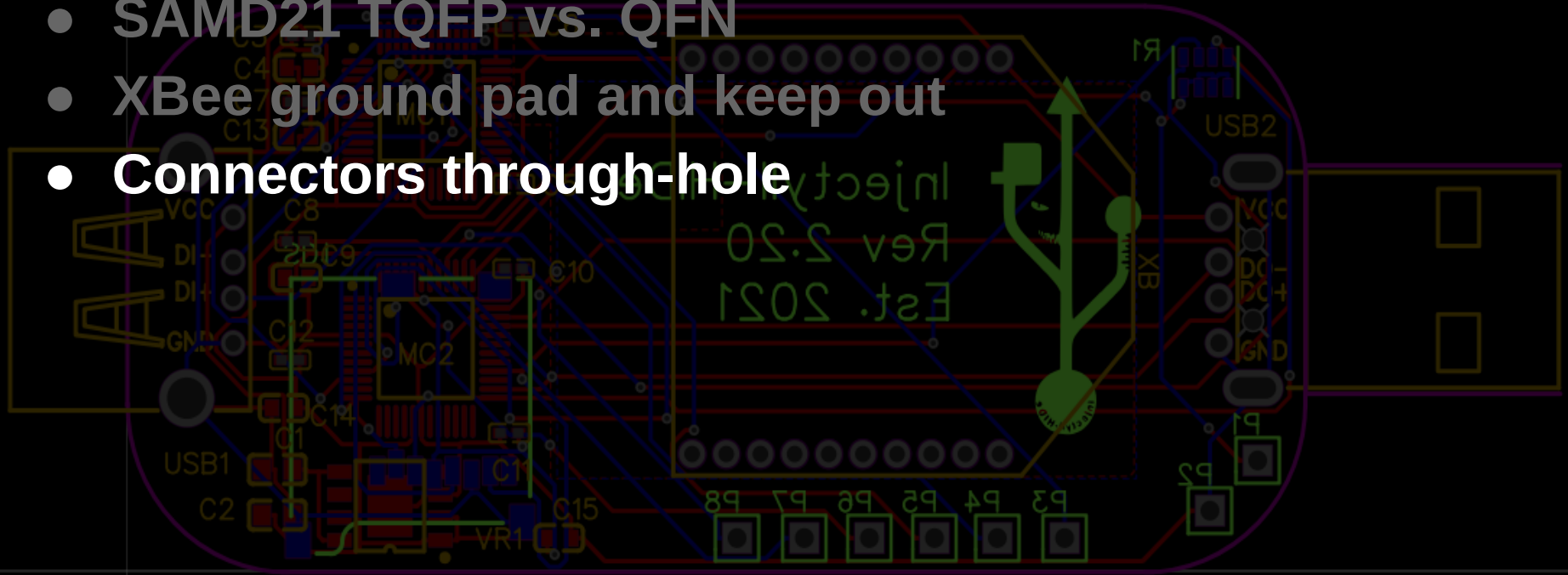
Component Mounting

- SAMD21 TQFP vs. QFN
- **XBee ground pad and keep out**



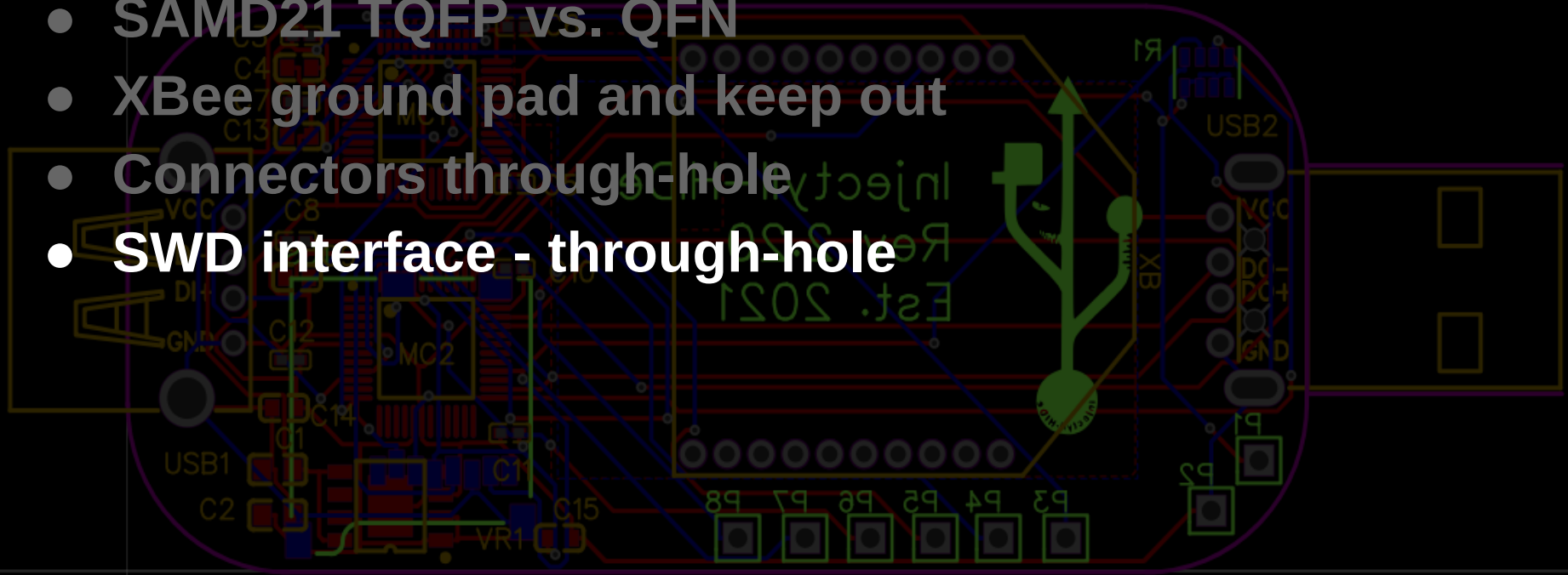
Component Mounting

- SAMD21 TQFP vs. QFN
- XBee ground pad and keep out
- **Connectors through-hole**



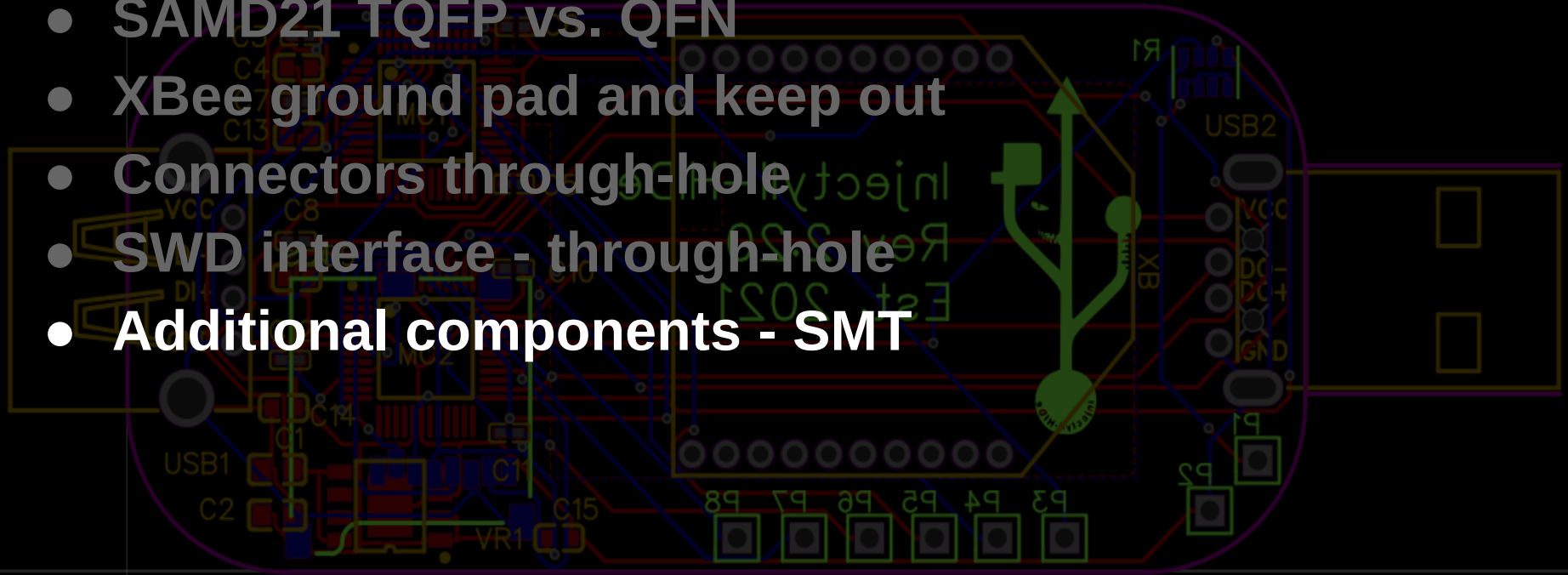
Component Mounting

- SAMD21 TQFP vs. QFN
- XBee ground pad and keep out
- Connectors through-hole
- **SWD interface - through-hole**

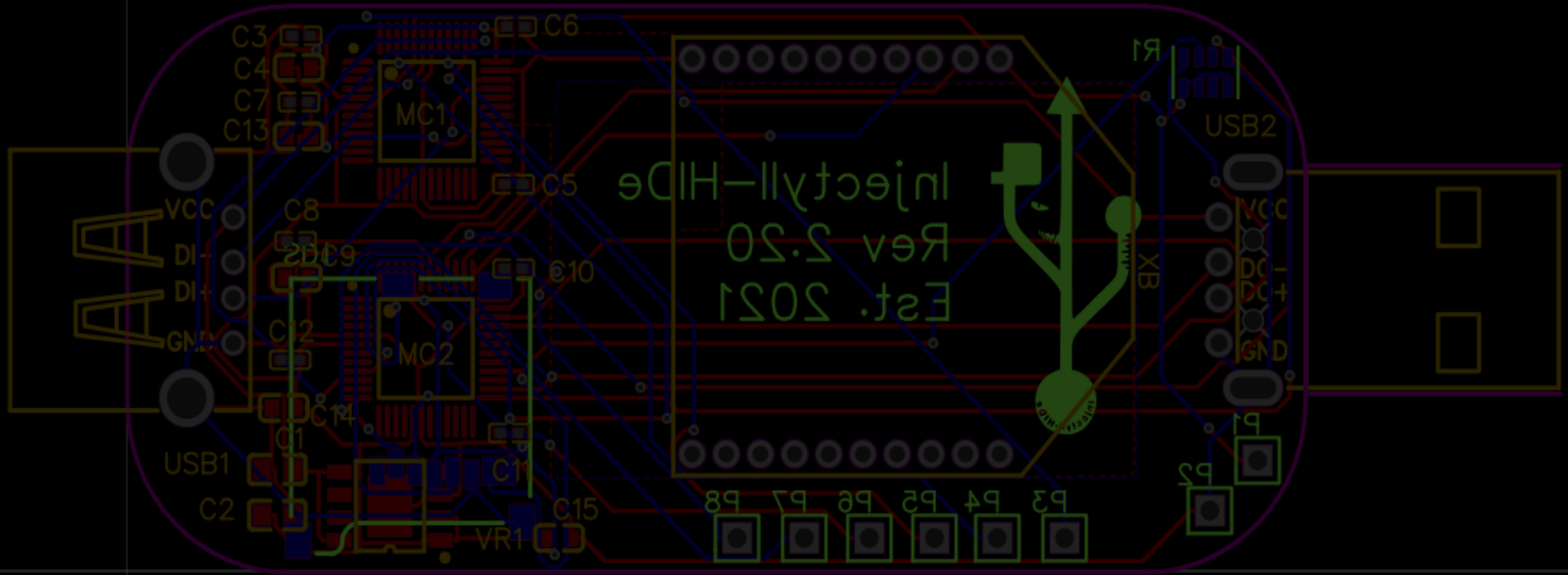


Component Mounting

- SAMD21 TQFP vs. QFN
- XBee ground pad and keep out
- Connectors through-hole
- SWD interface - through-hole
- **Additional components - SMT**

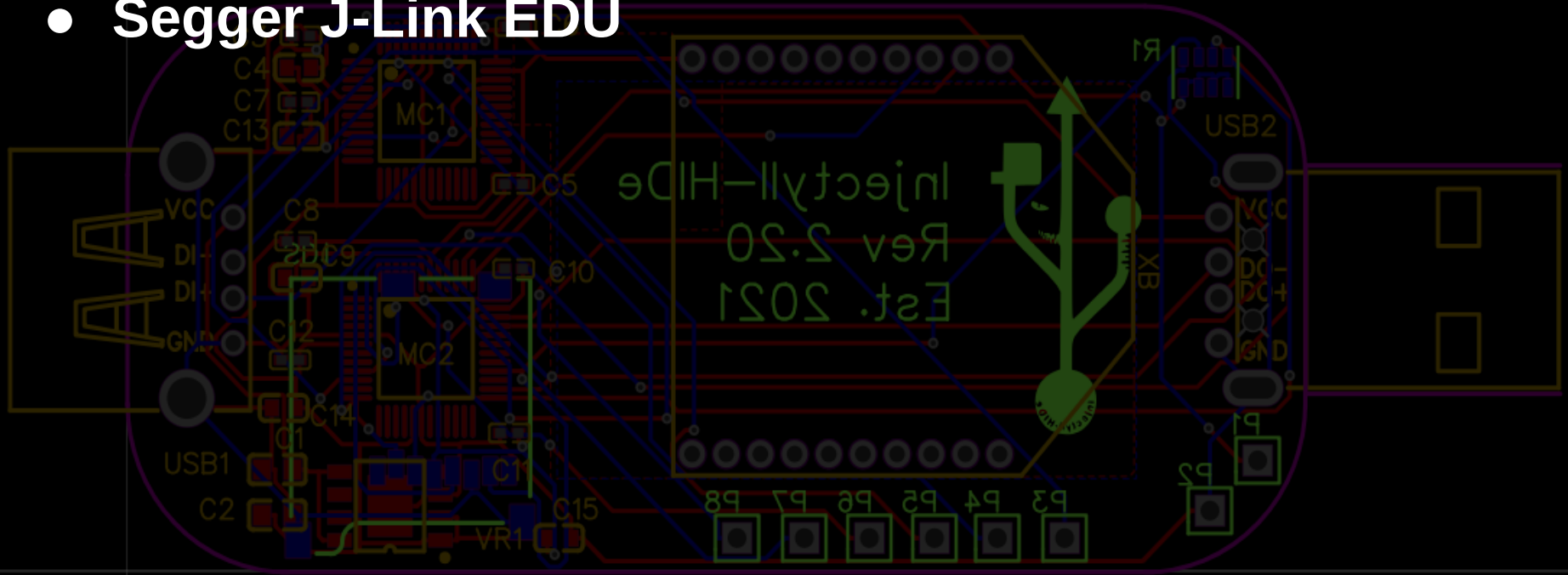


SWD Debugging



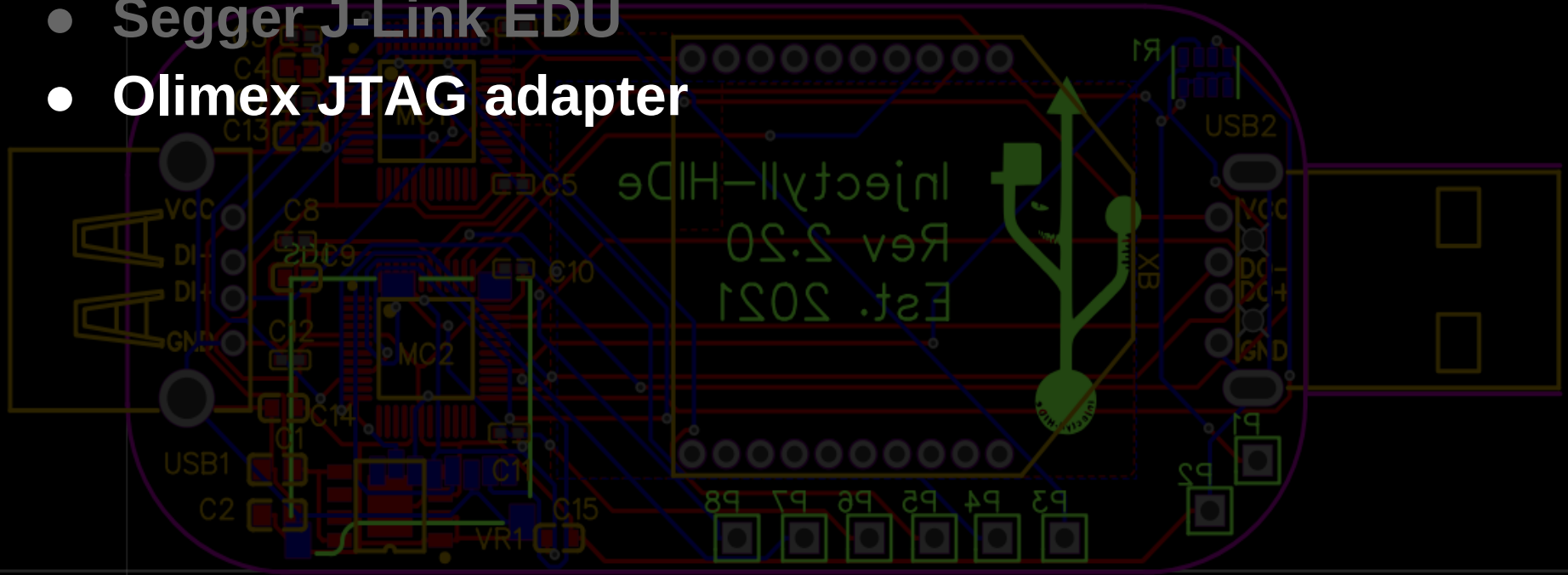
SWD Debugging

- **Segger J-Link EDU**



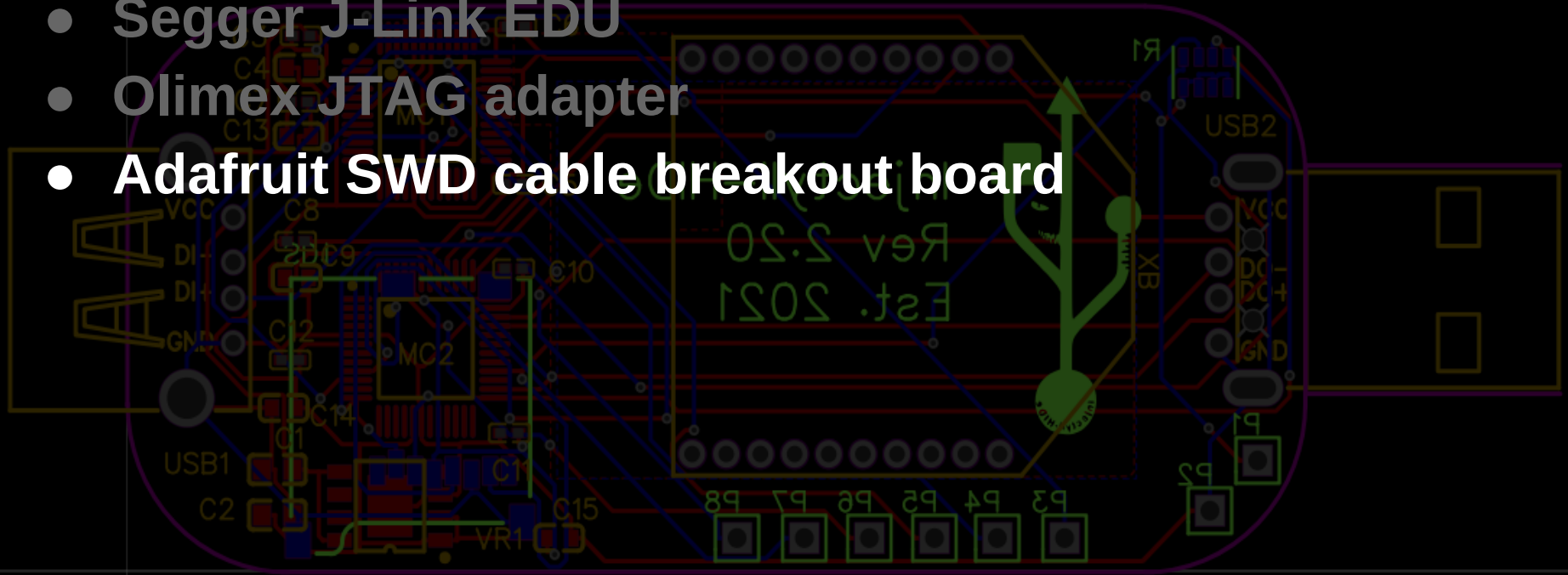
SWD Debugging

- Segger J-Link EDU
- **Olimex JTAG adapter**



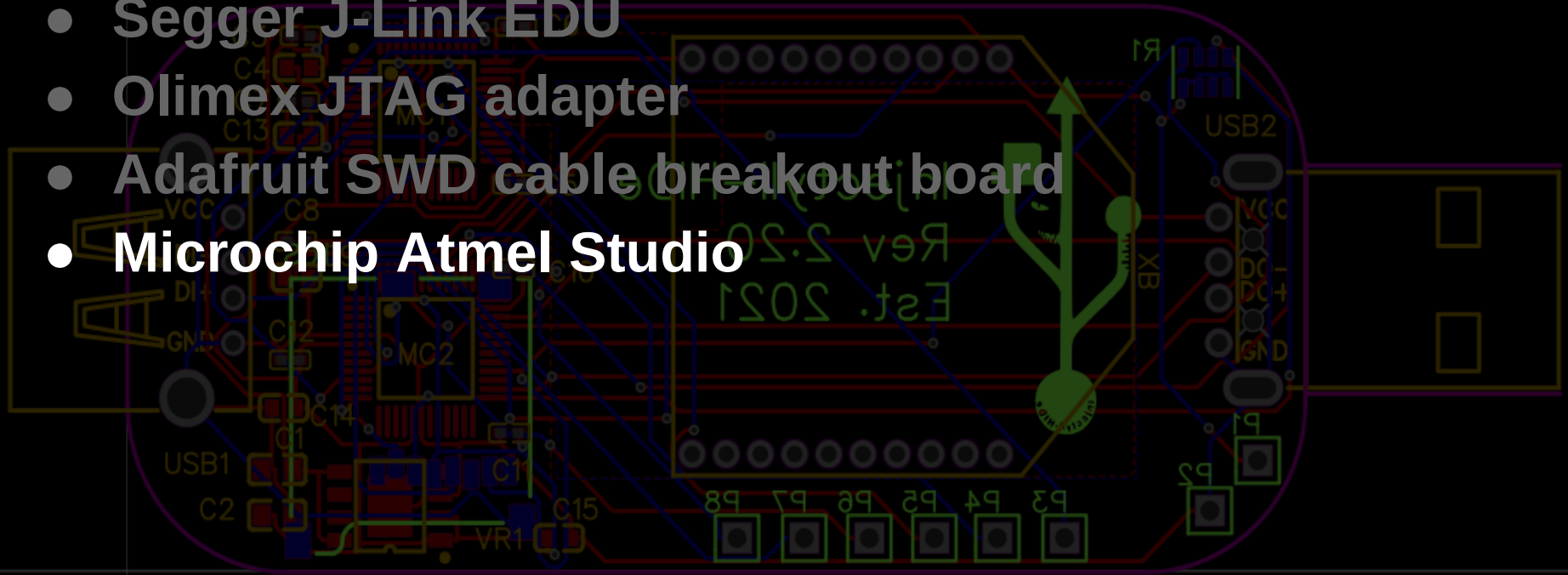
SWD Debugging

- Segger J-Link EDU
- Olimex JTAG adapter
- **Adafruit SWD cable breakout board**

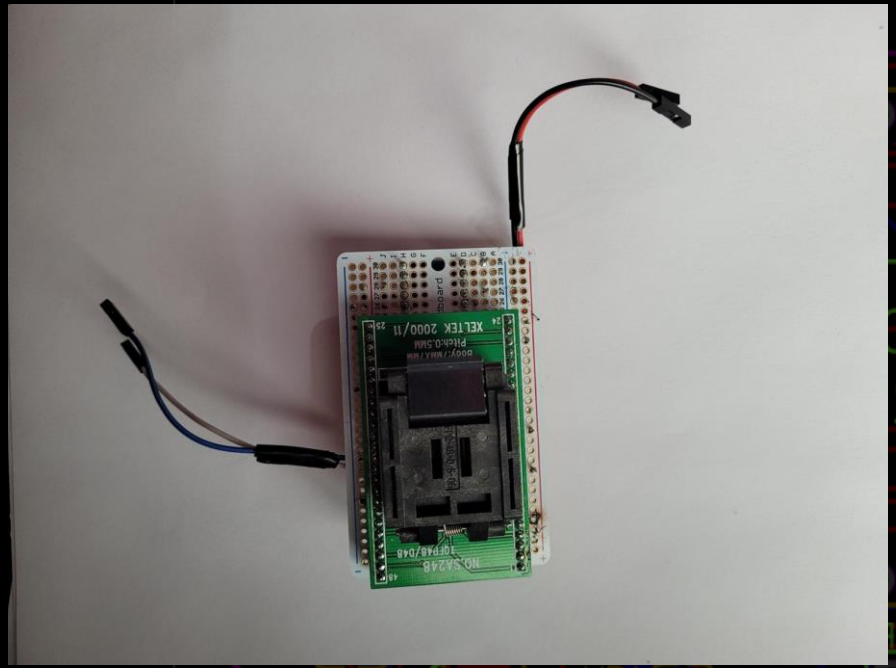


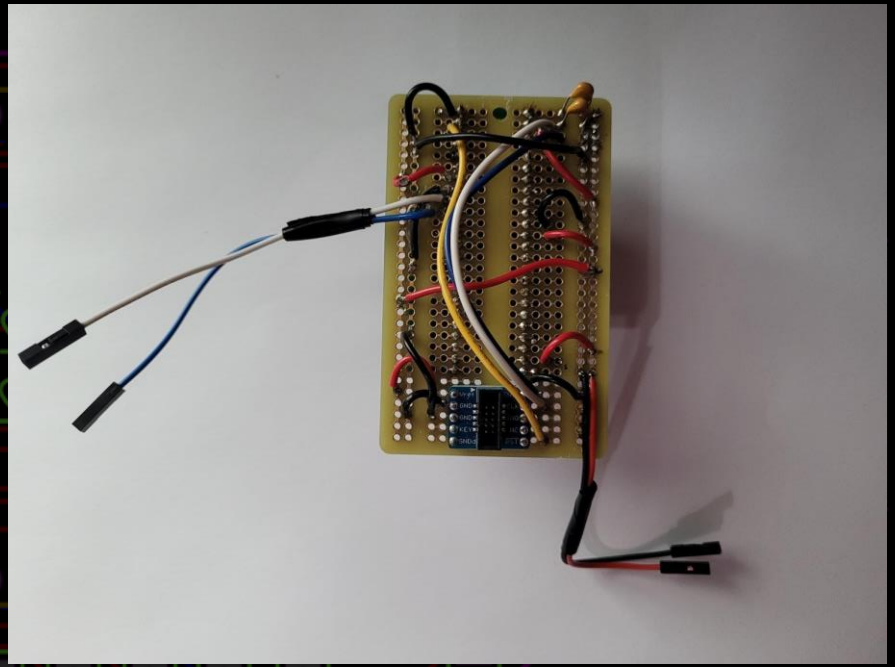
SWD Debugging

- Segger J-Link EDU
- Olimex JTAG adapter
- Adafruit SWD cable breakout board
- **Microchip Atmel Studio**

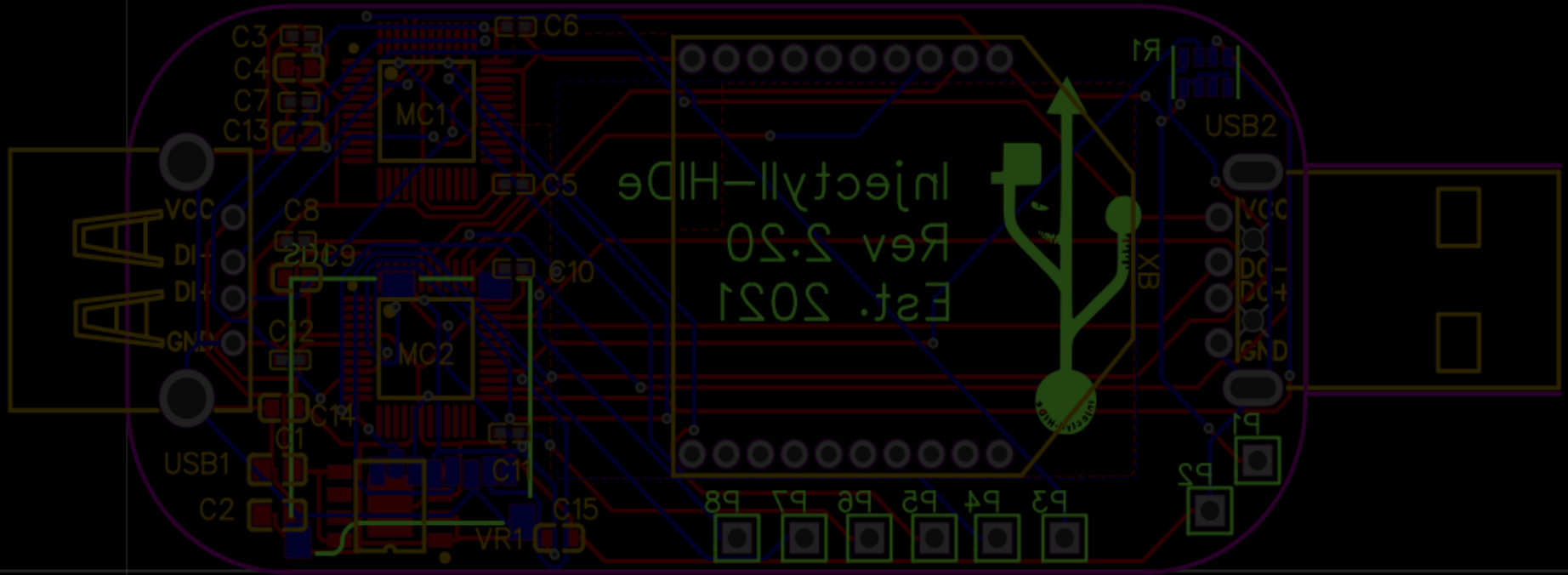


Single Test Socket





Single Test Socket Lessons Learned



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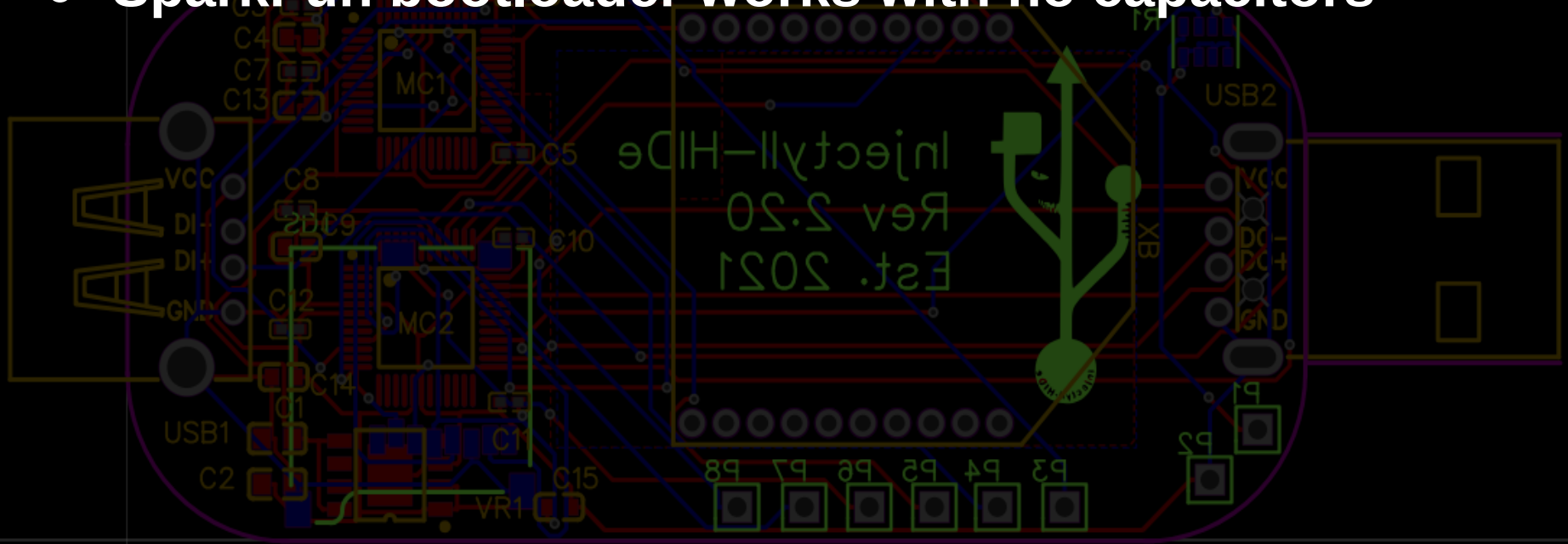
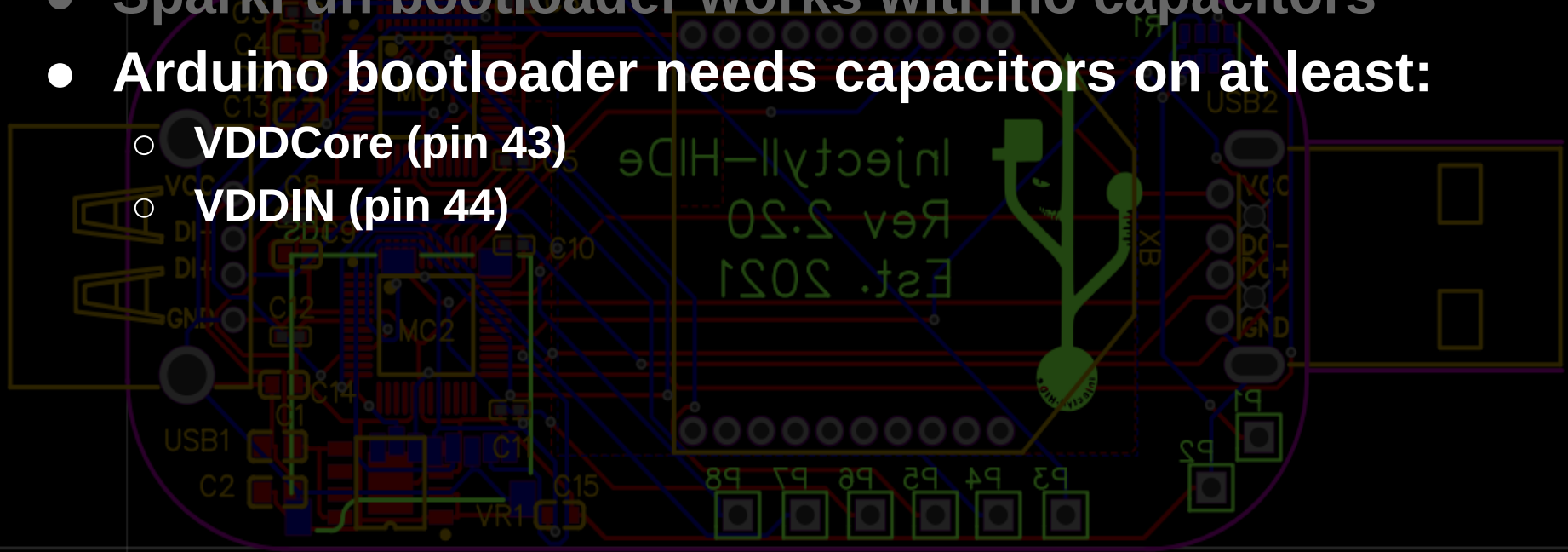
Single Test Socket Lessons Learned

- **SparkFun bootloader works with no capacitors**

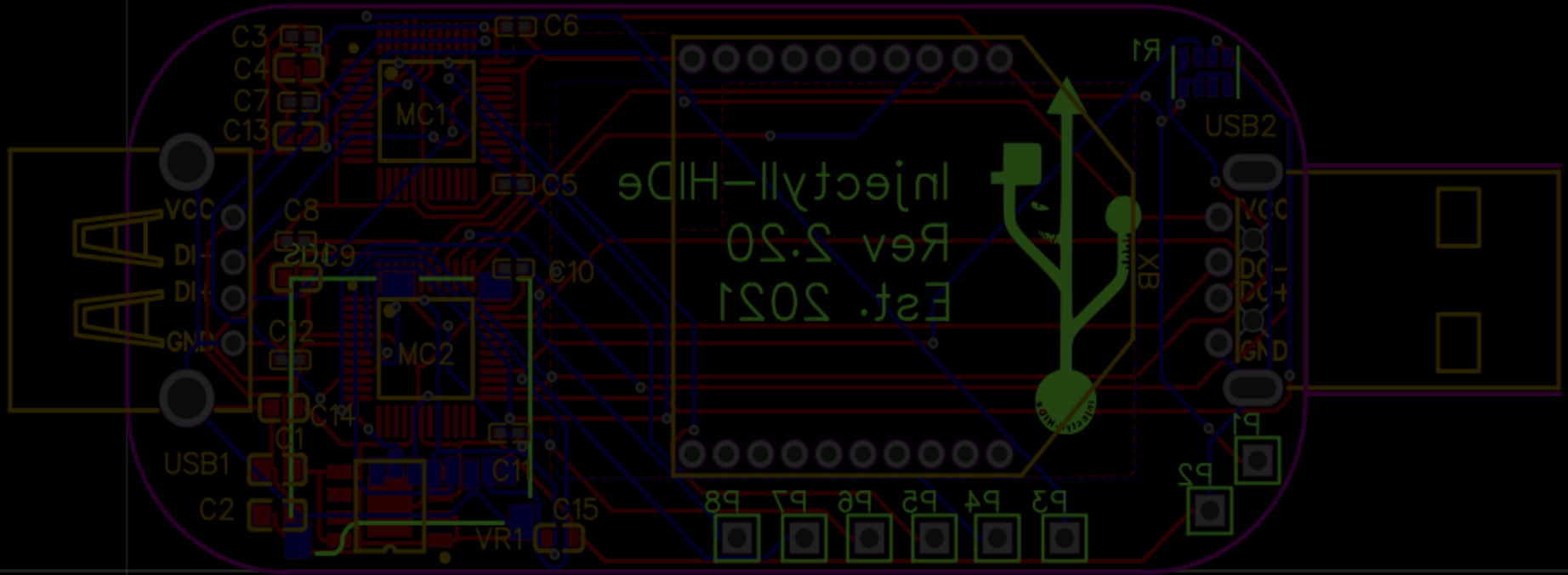


Single Test Socket Lessons Learned

- SparkFun bootloader works with no capacitors
- **Arduino bootloader needs capacitors on at least:**
  - **VDDCore (pin 43)**
  - **VDDIN (pin 44)**



Single Test Socket Conclusion



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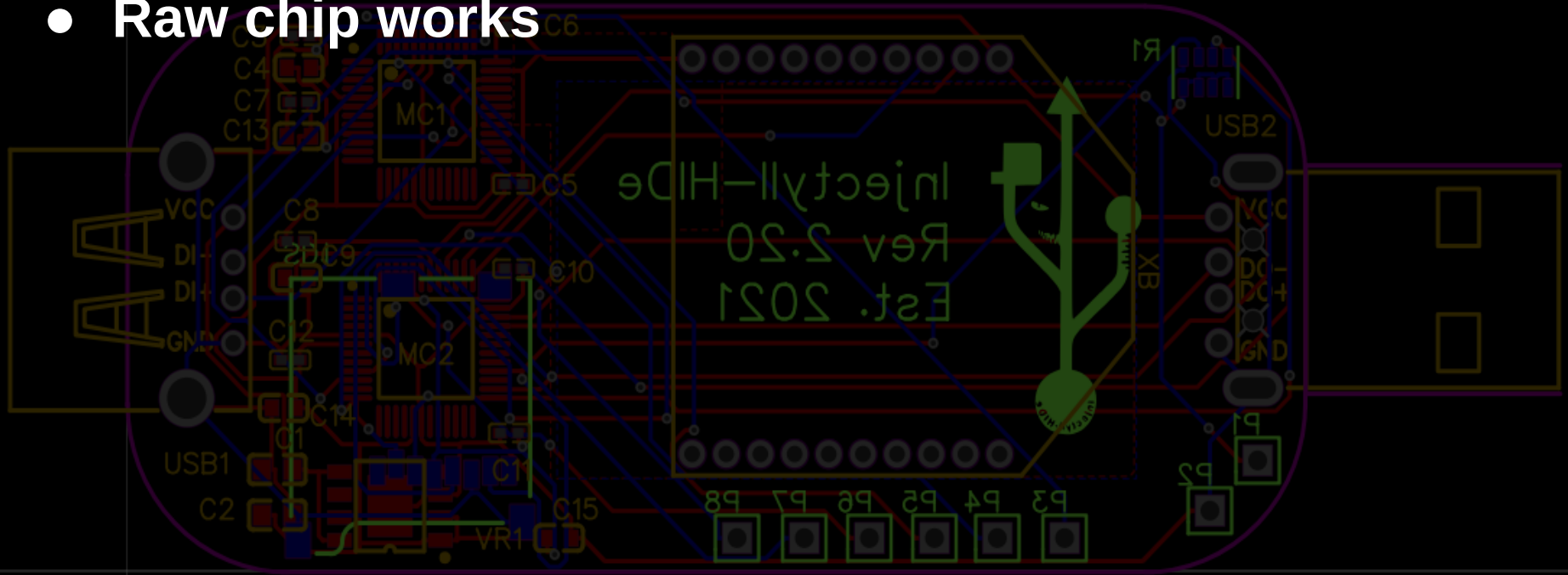
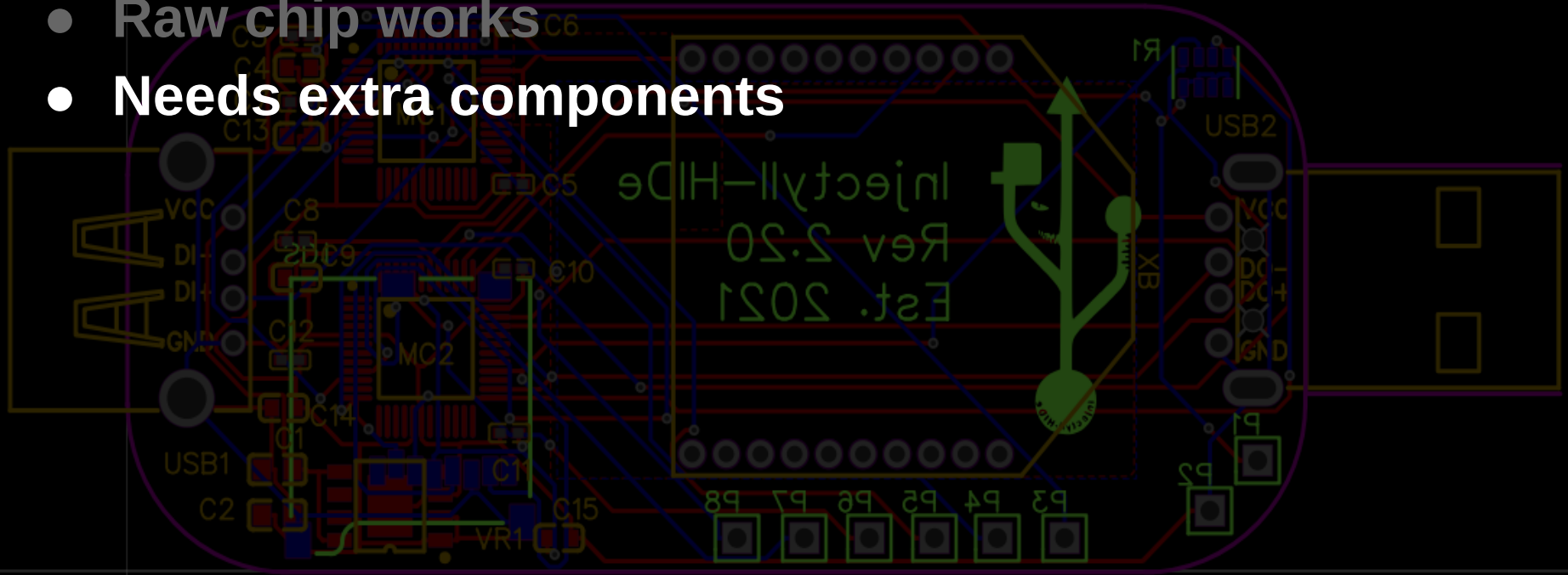
Single Test Socket Conclusion

- **Raw chip works**

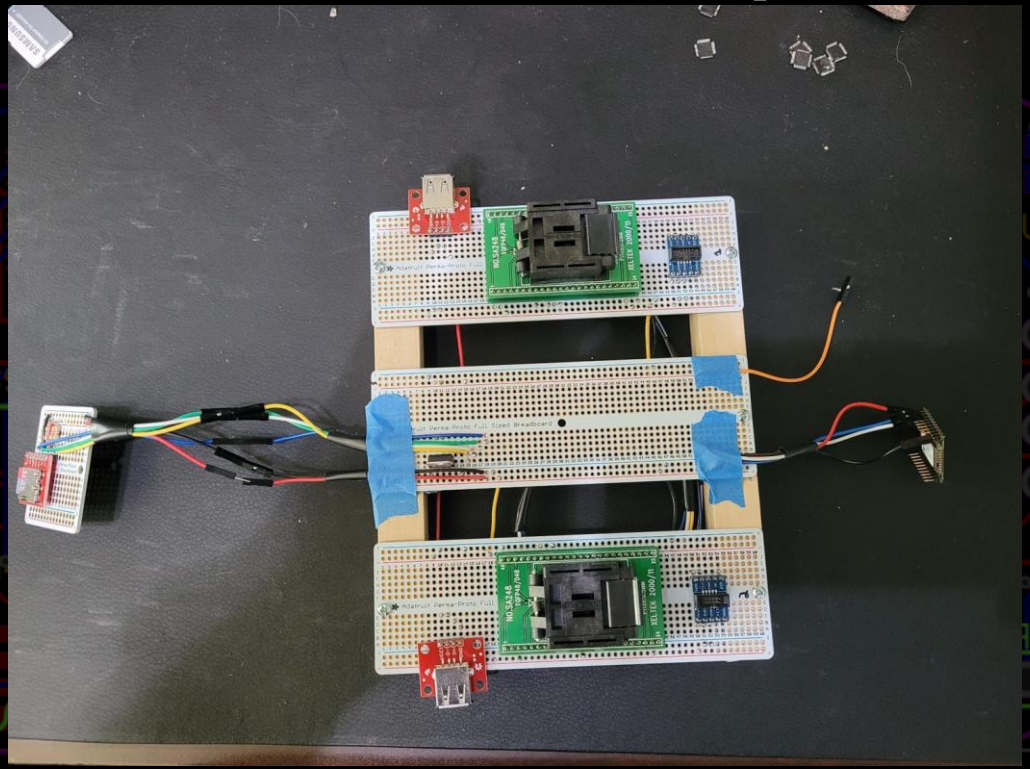


Single Test Socket Conclusion

- Raw chip works
- **Needs extra components**



Full Mock Up



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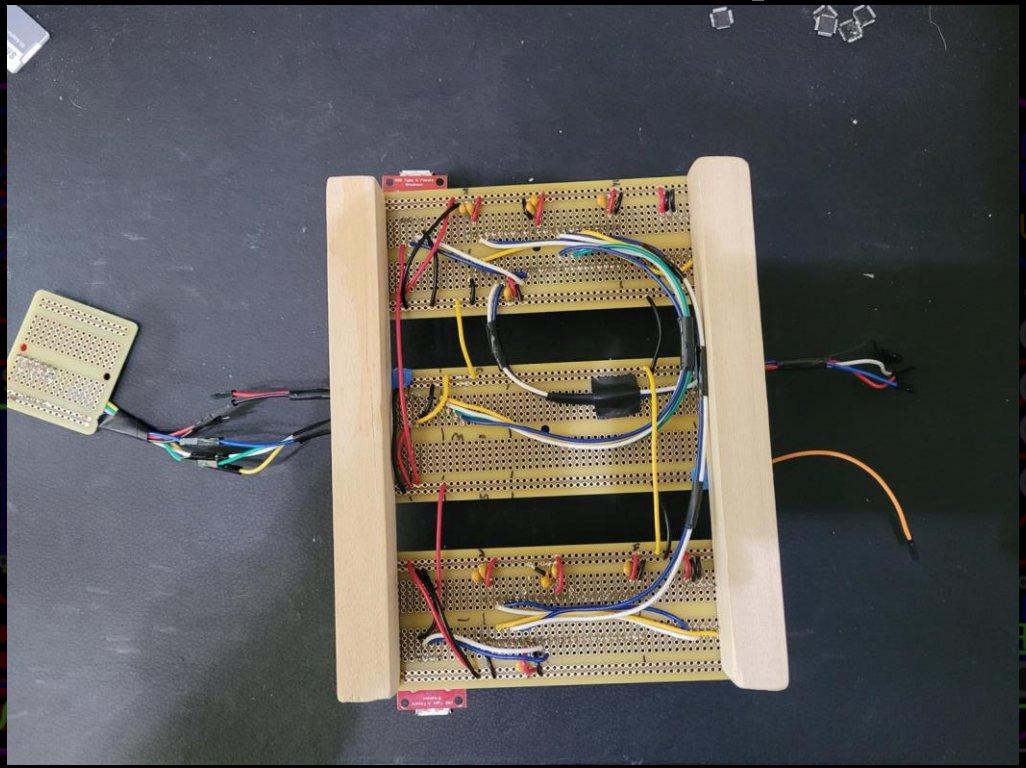
Full Mock Up



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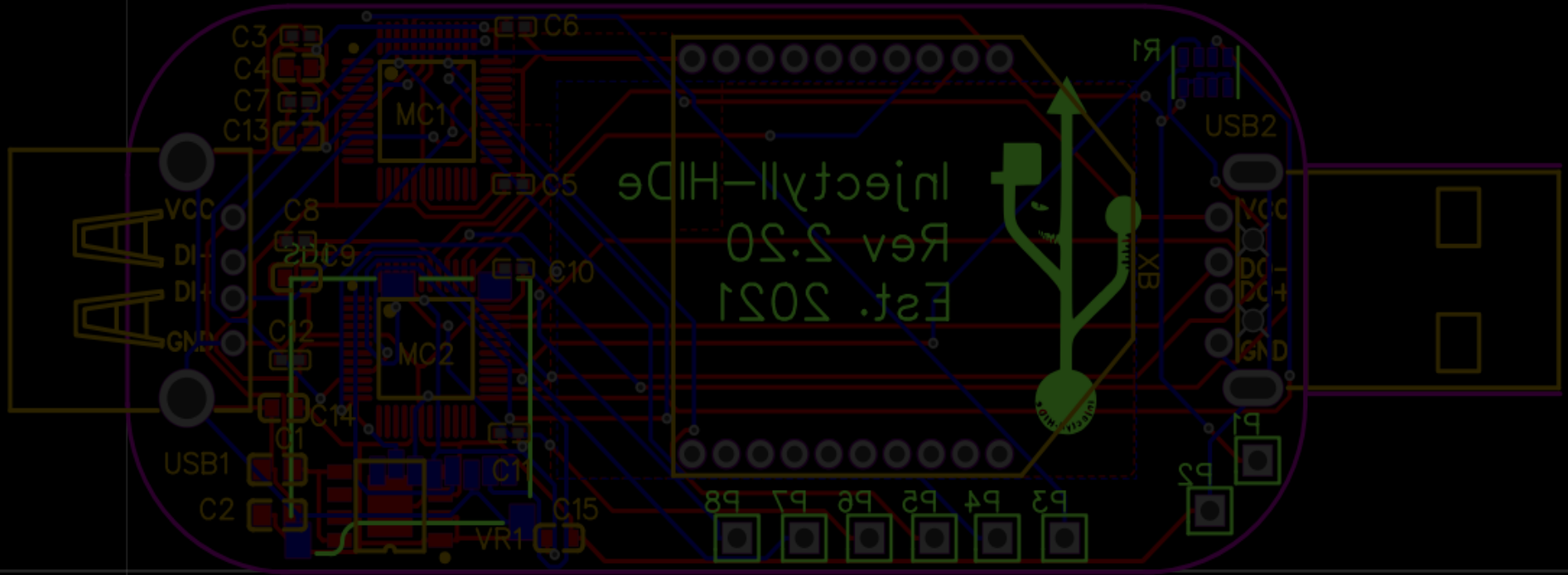
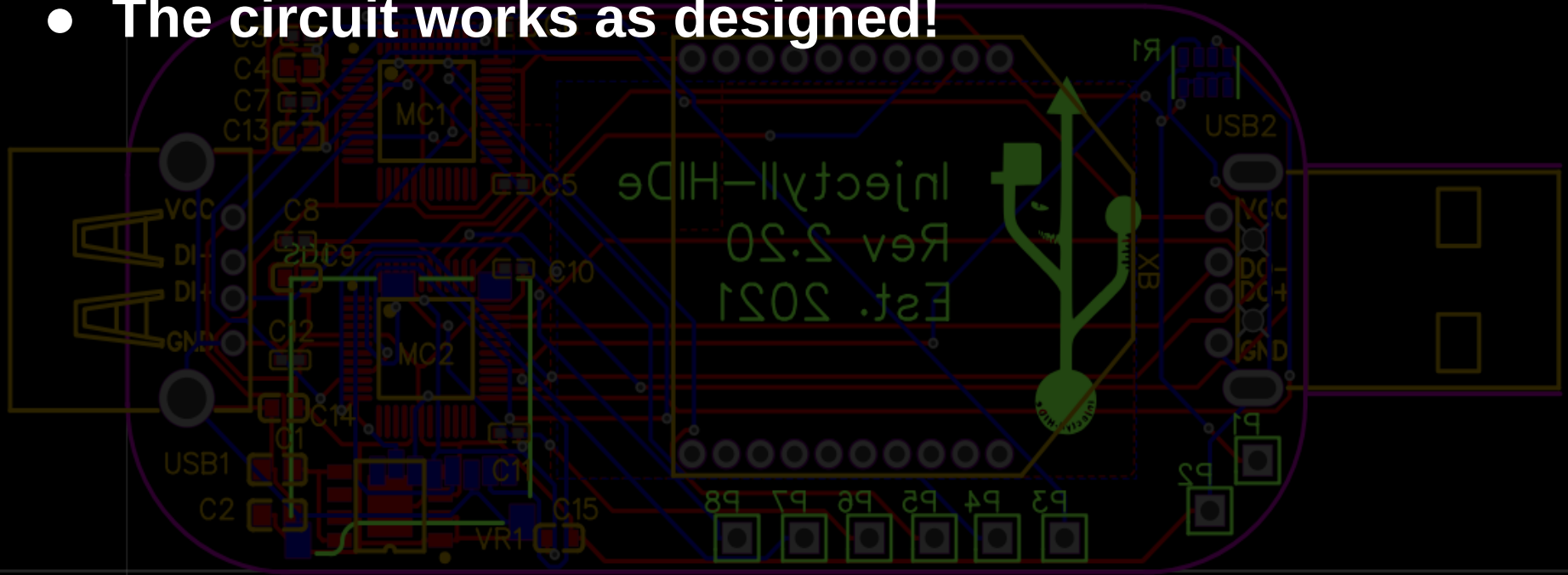
Full Mock Up Conclusion



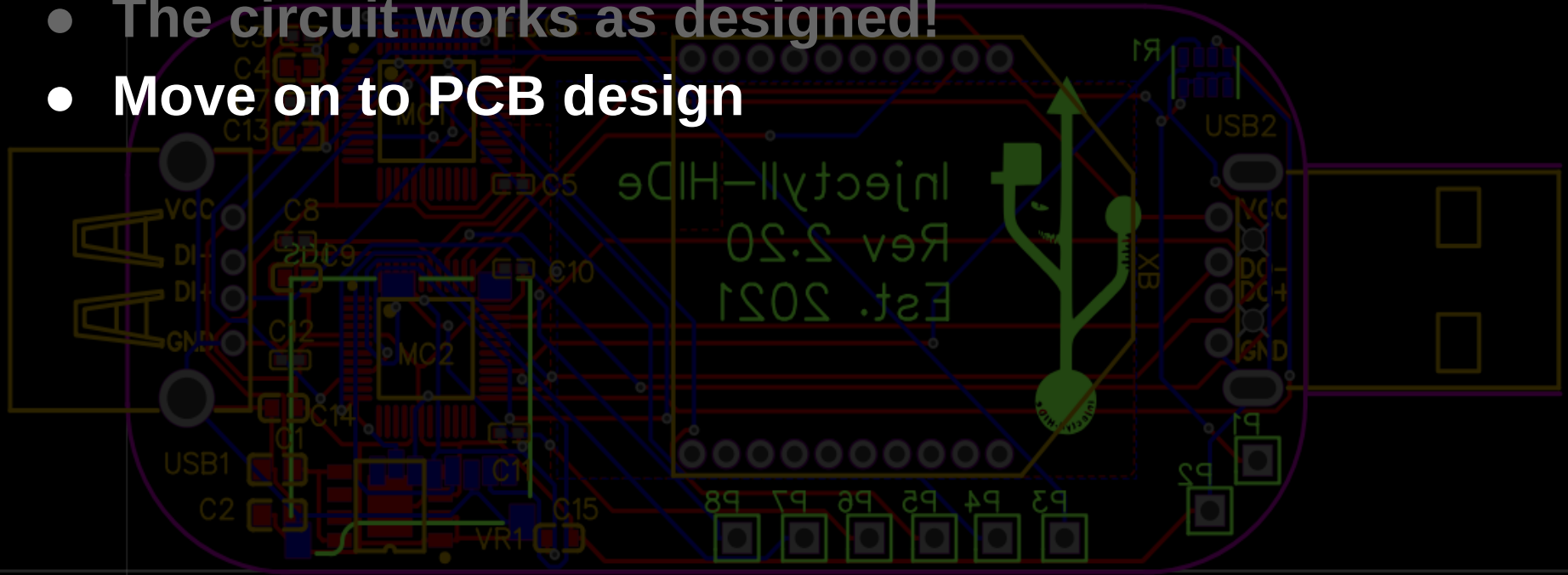
Full Mock Up Conclusion

- **The circuit works as designed!**

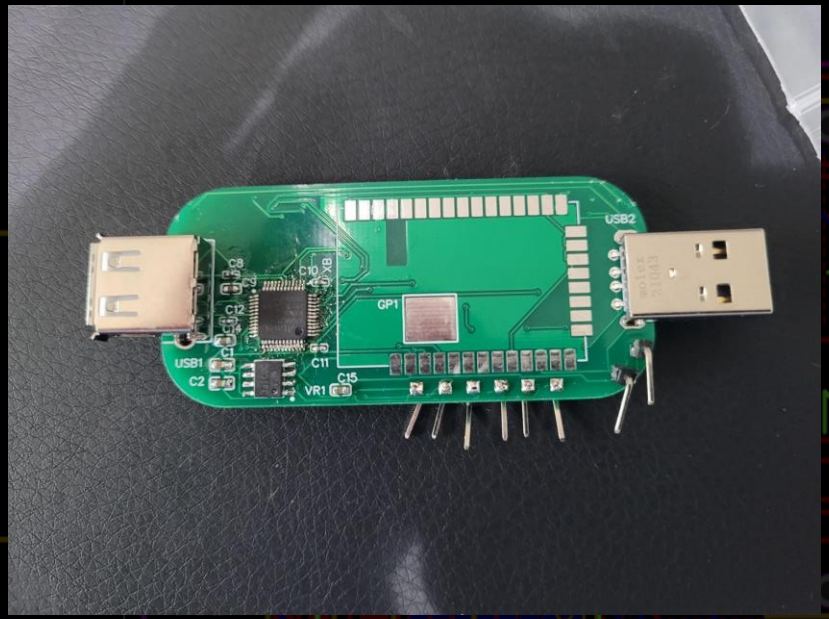


Full Mock Up Conclusion

- The circuit works as designed!
- **Move on to PCB design**



PCB Prototype 1



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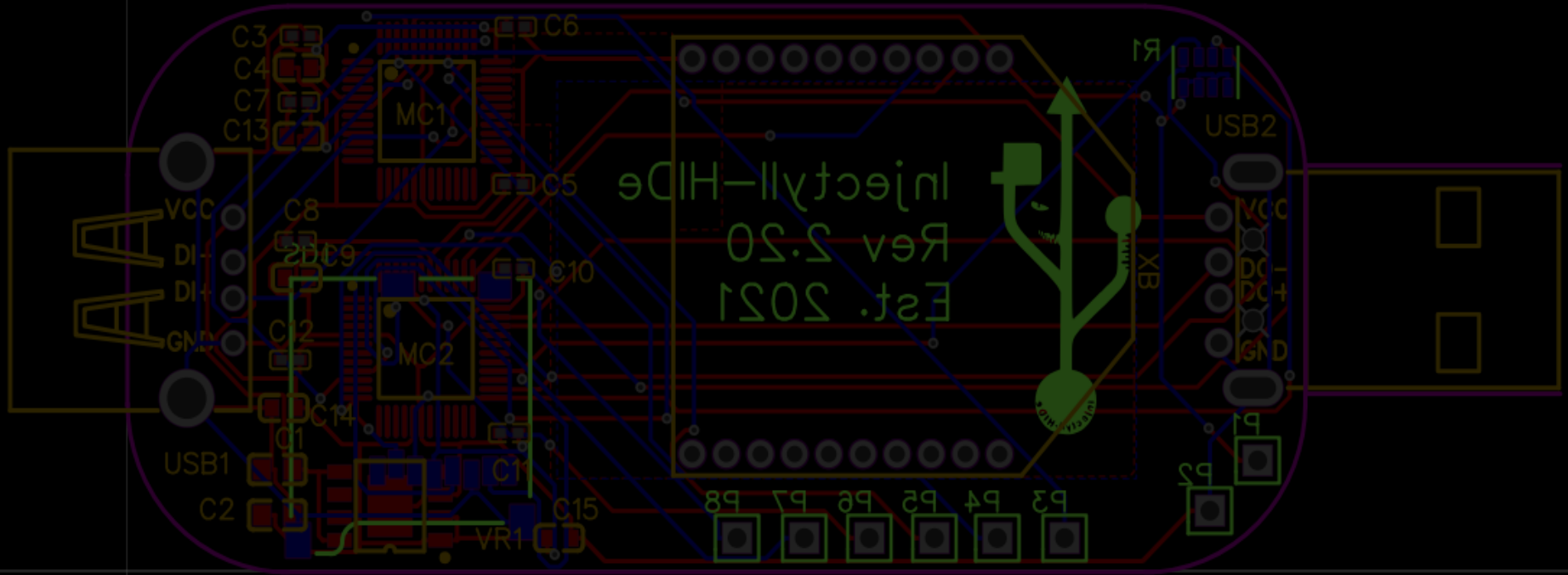
PCB Prototype #1 Lessons Learned



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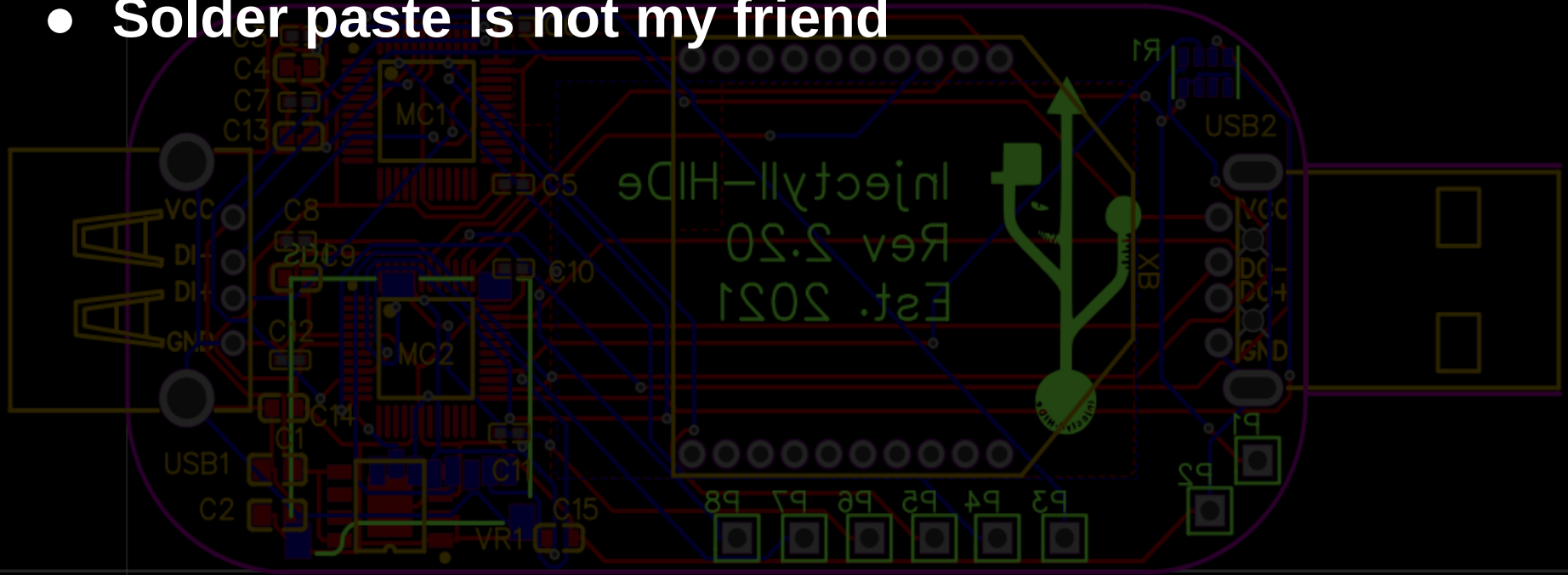
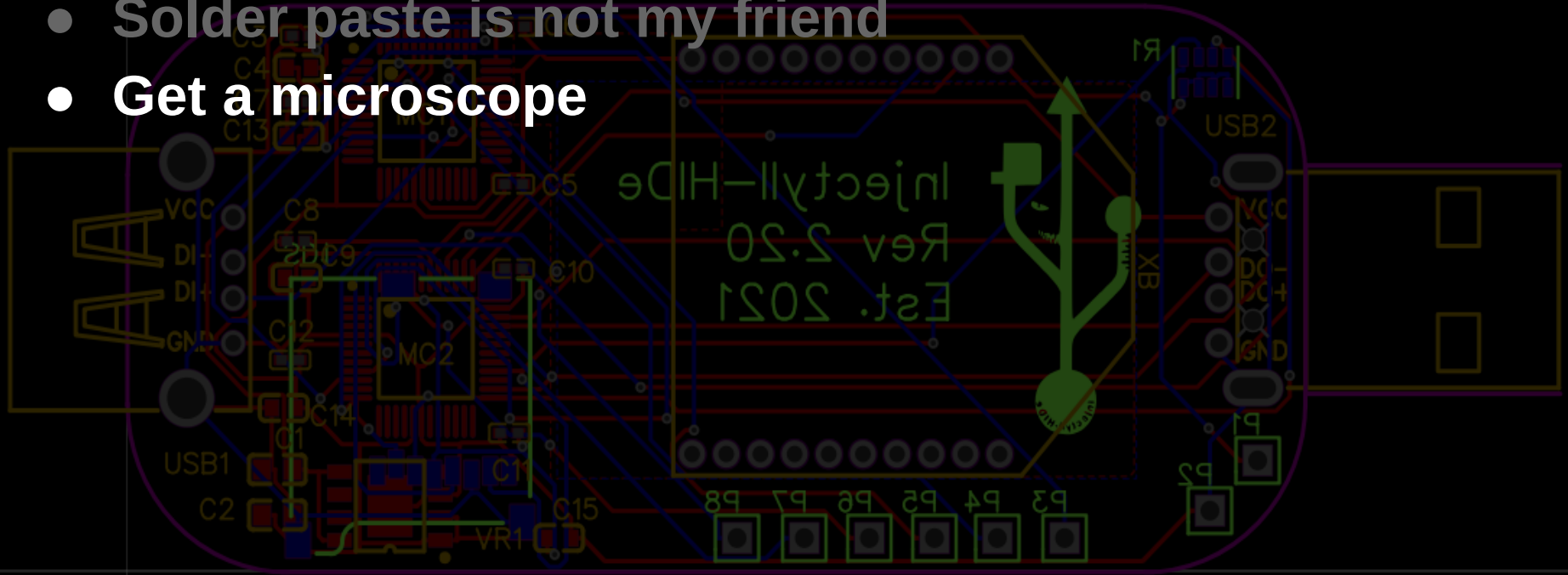
PCB Prototype #1 Lessons Learned

- **Solder paste is not my friend**



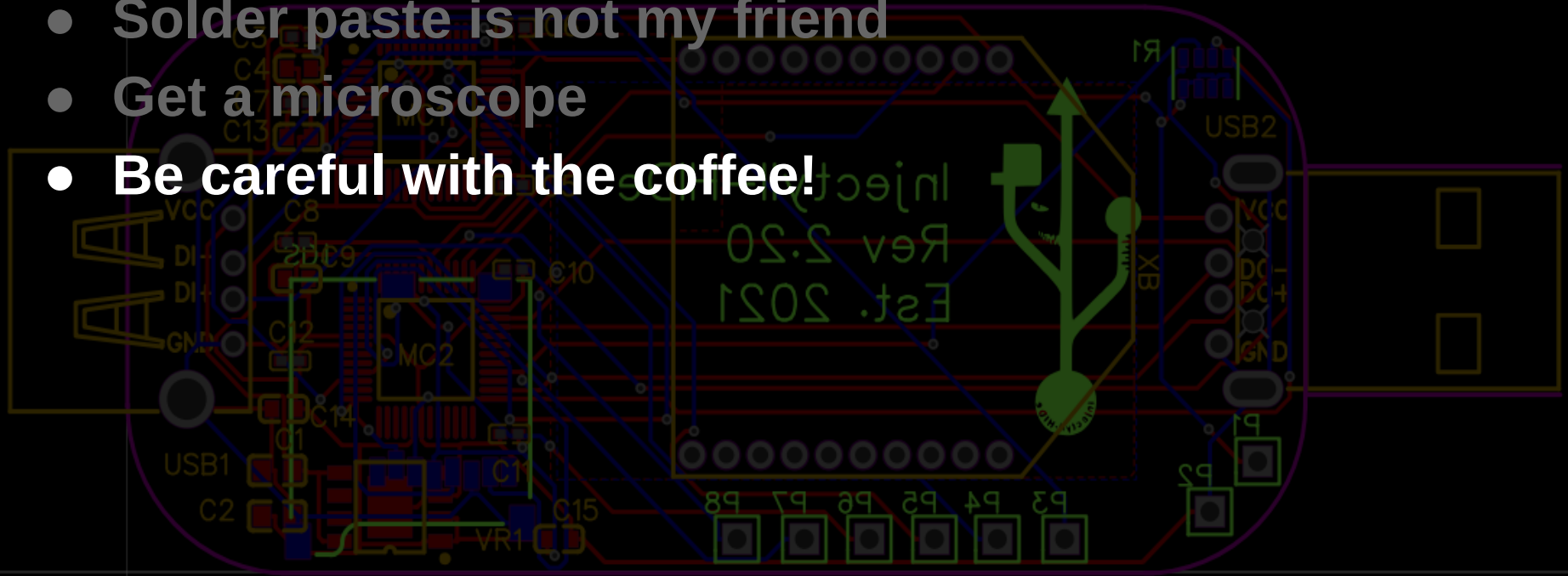
PCB Prototype #1 Lessons Learned

- Solder paste is not my friend
- **Get a microscope**



PCB Prototype #1 Lessons Learned

- Solder paste is not my friend
- Get a microscope
- **Be careful with the coffee!**

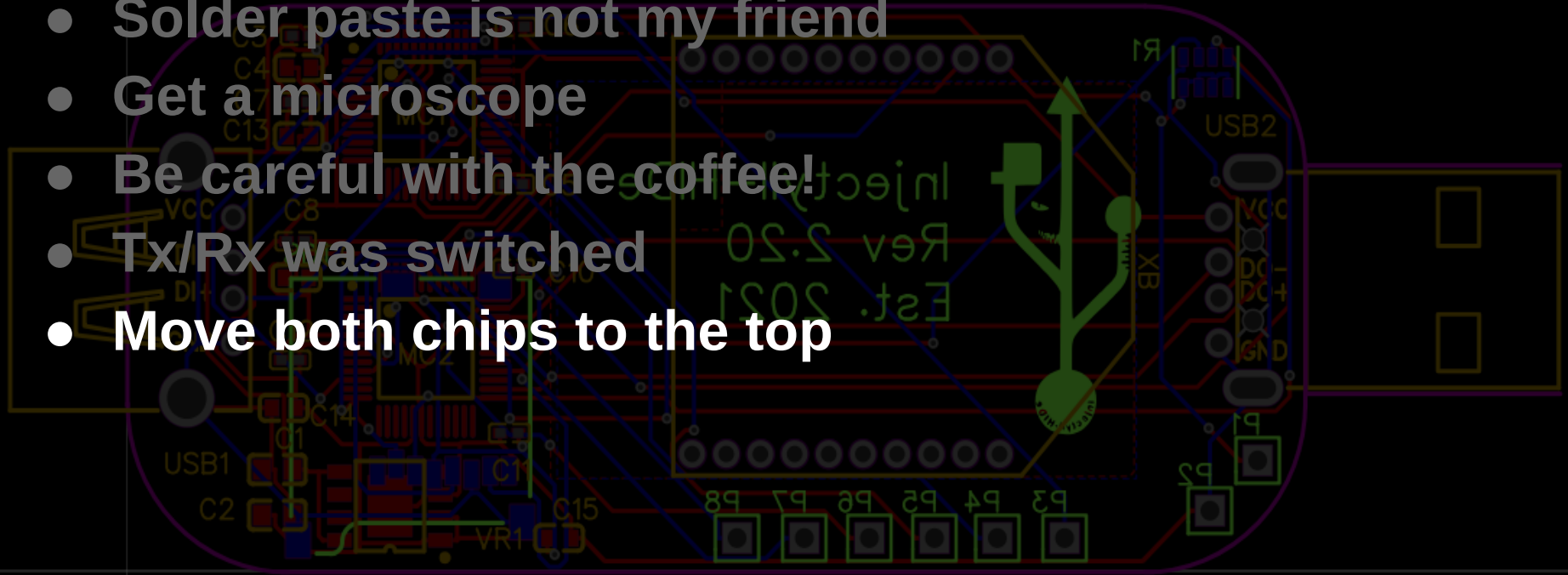


PCB Prototype #1 Lessons Learned

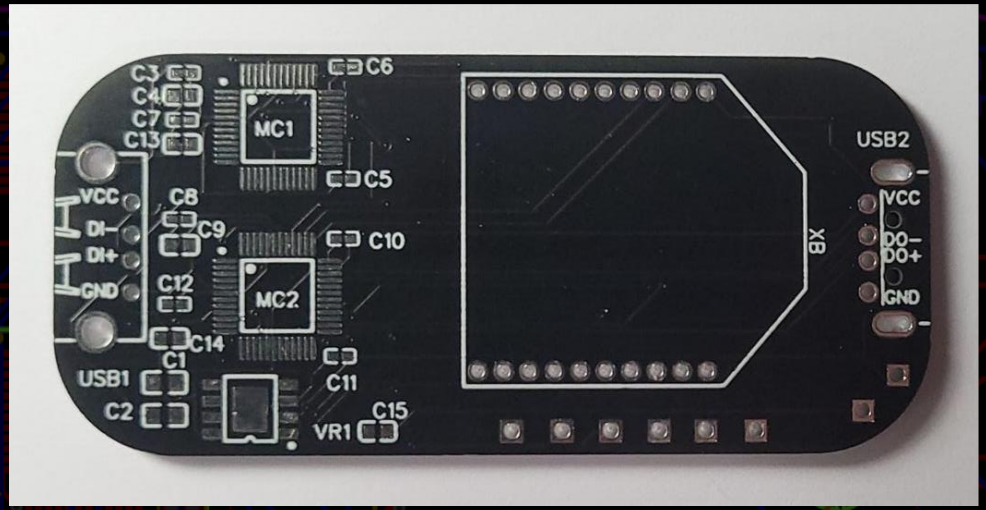
- Solder paste is not my friend
- Get a microscope
- Be careful with the coffee!
- **Tx/Rx was switched**

PCB Prototype #1 Lessons Learned

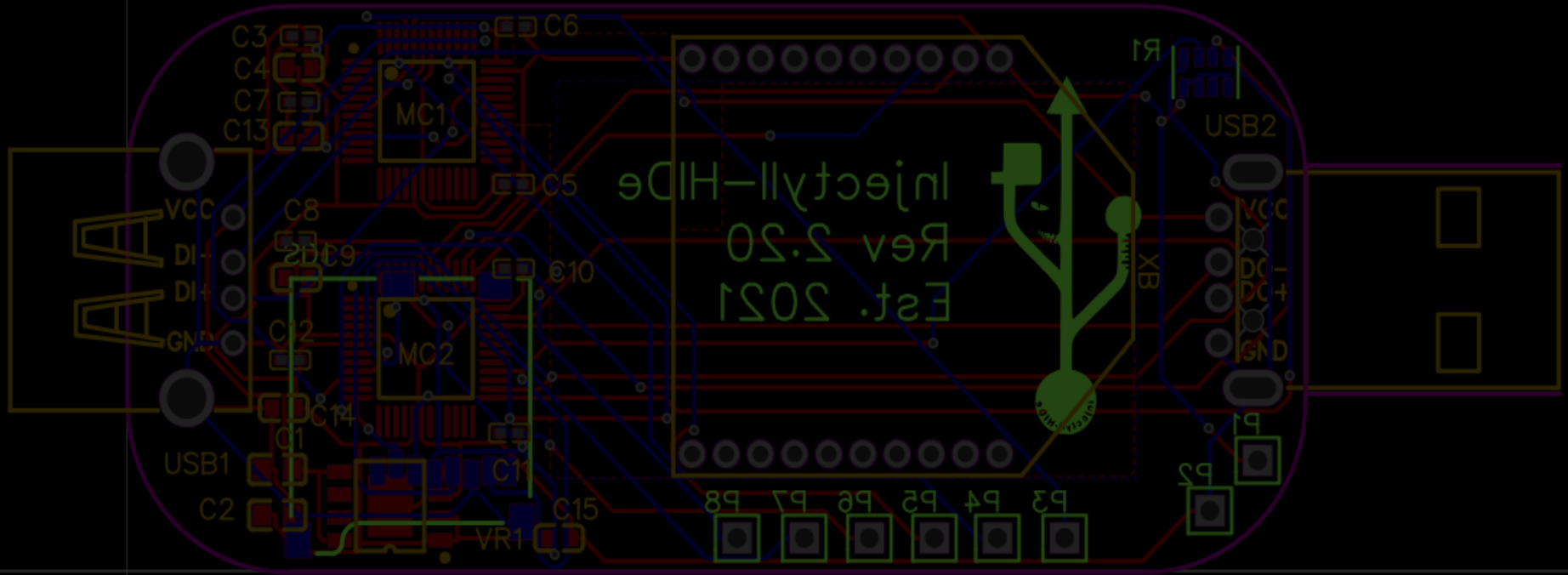
- Solder paste is not my friend
- Get a microscope
- Be careful with the coffee!
- Tx/Rx was switched
- **Move both chips to the top**



PCB Prototype #2



PCB Prototype #2 Lessons Learned



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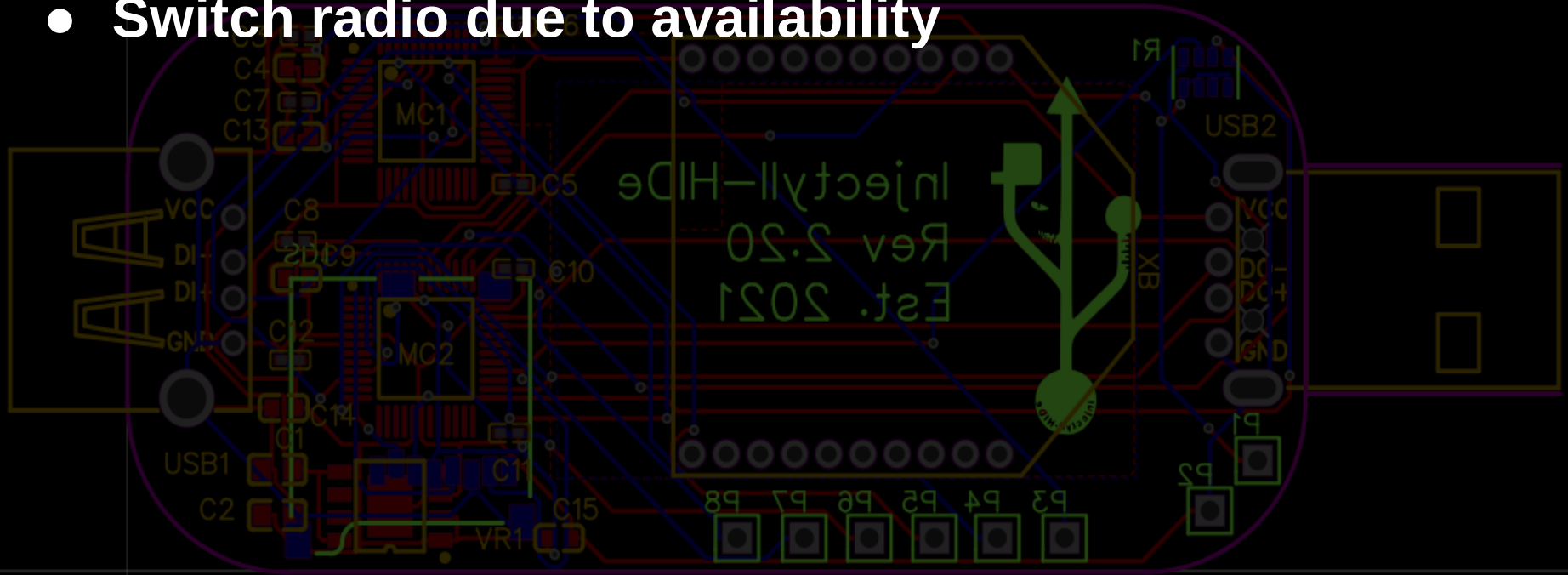
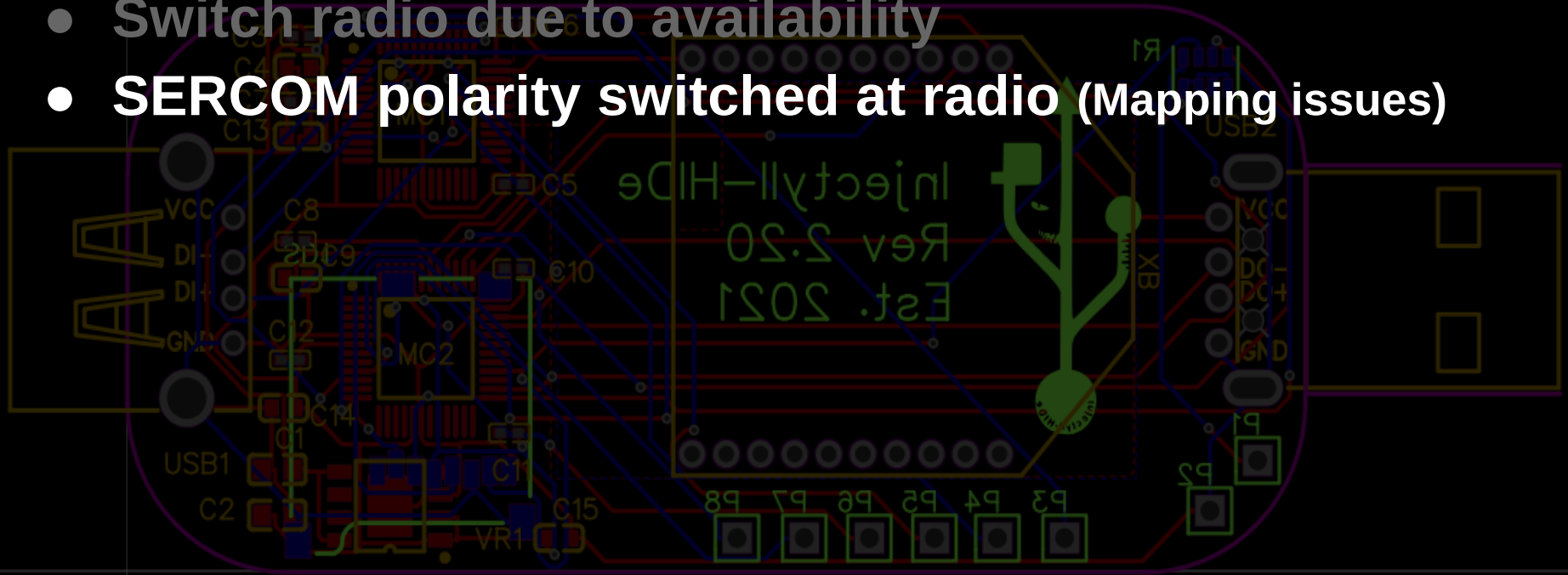
PCB Prototype #2 Lessons Learned

- **Switch radio due to availability**

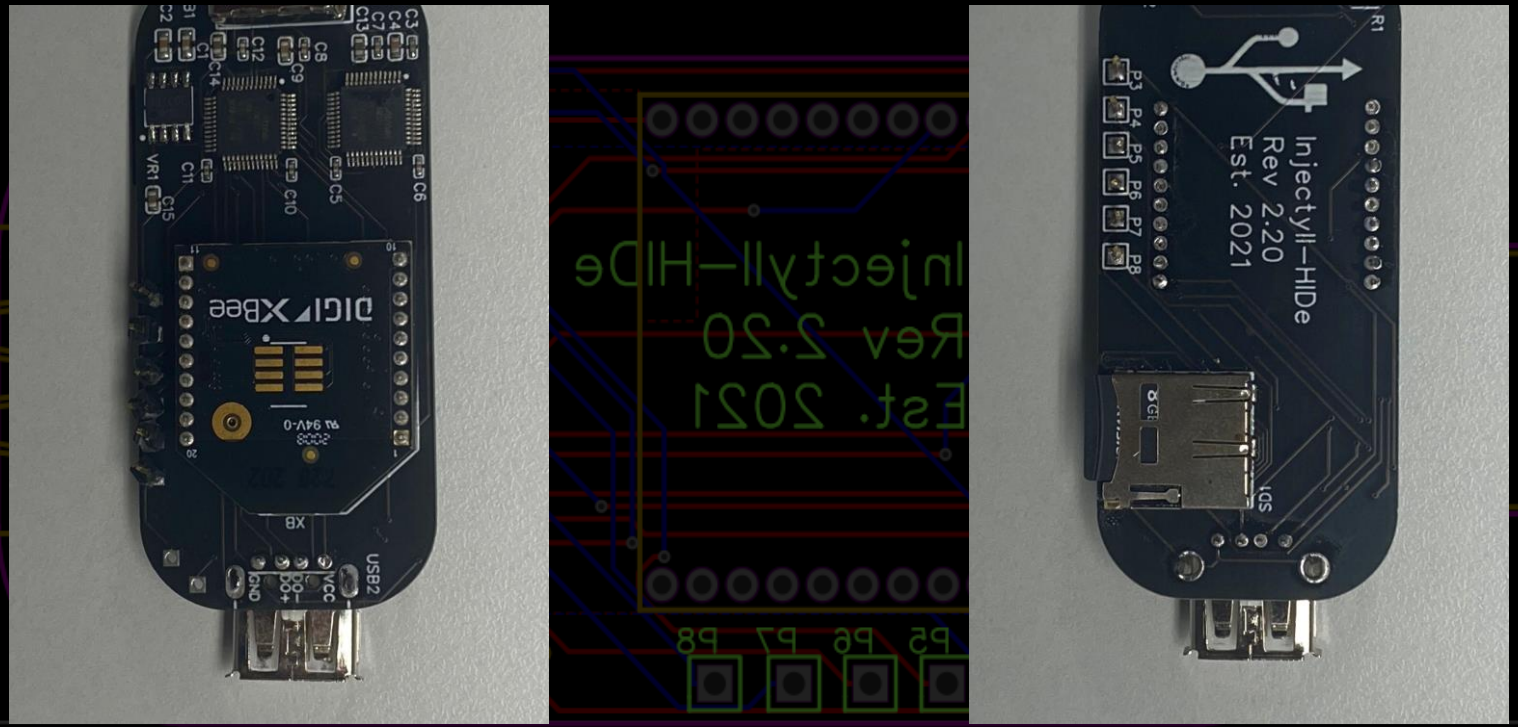


PCB Prototype #2 Lessons Learned

- Switch radio due to availability
- **SERCOM polarity switched at radio (Mapping issues)**



Final PCB Release



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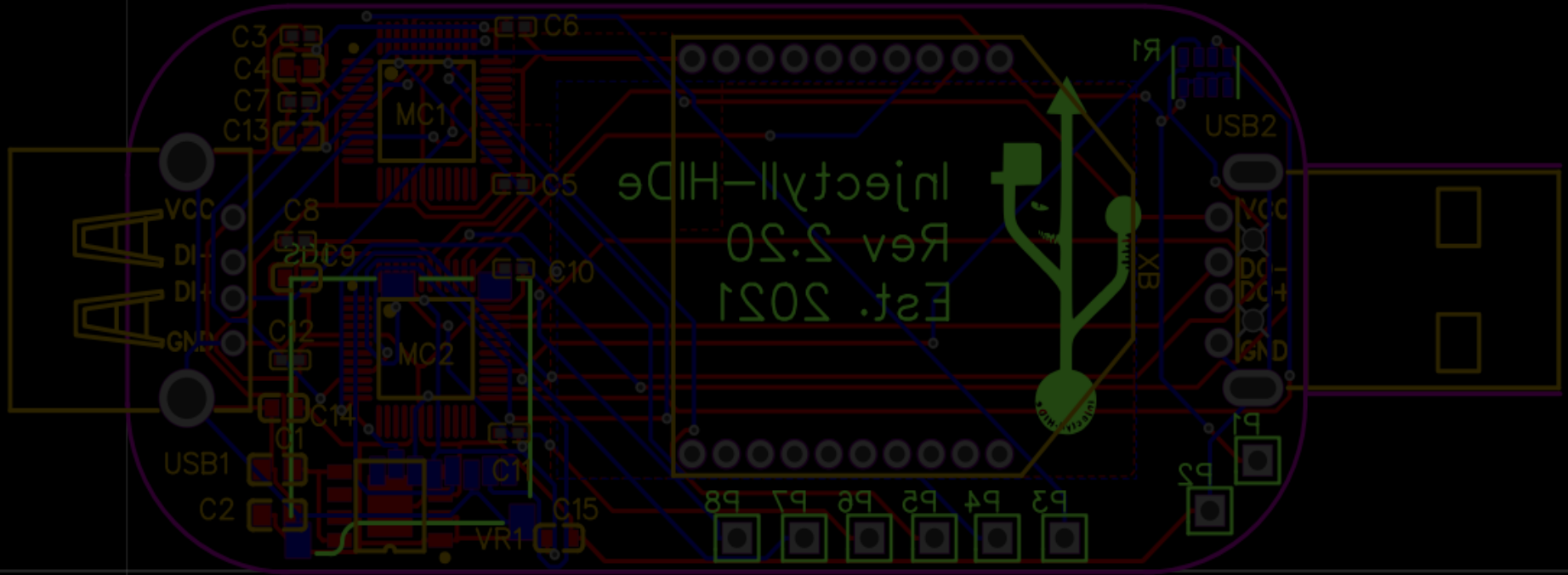
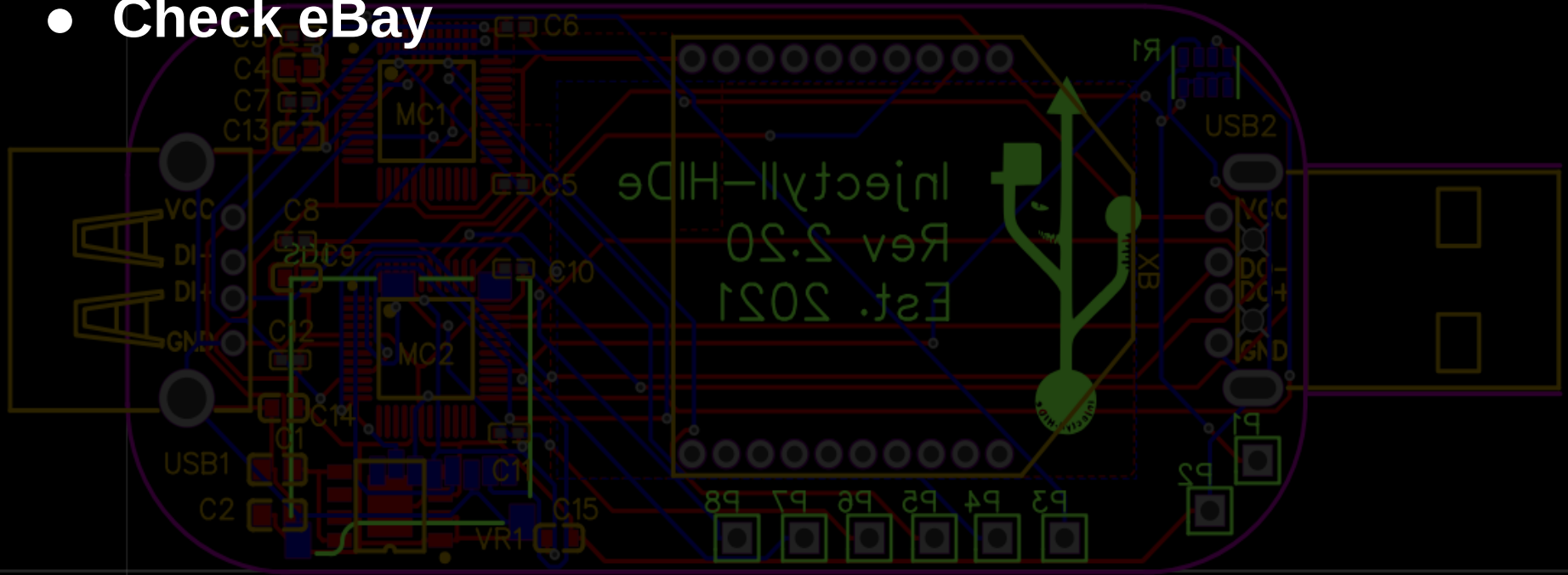
Navigating the Chip Shortage



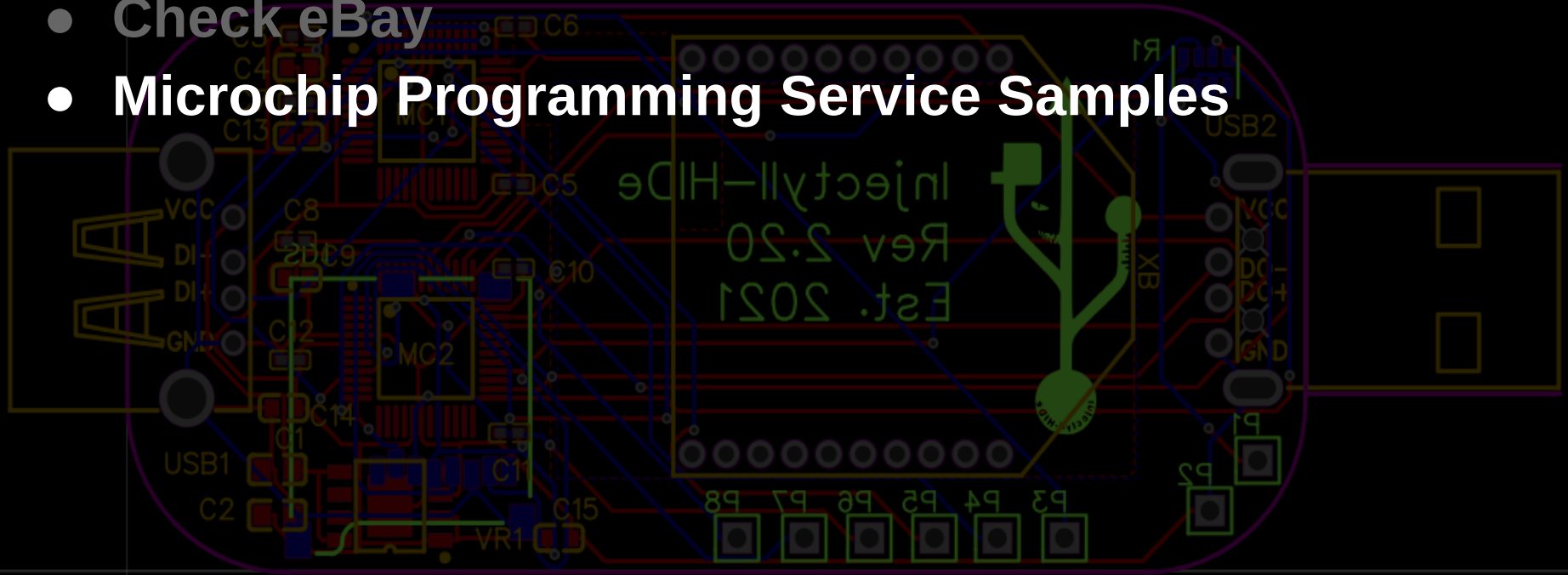
Navigating the Chip Shortage

- **Check eBay**



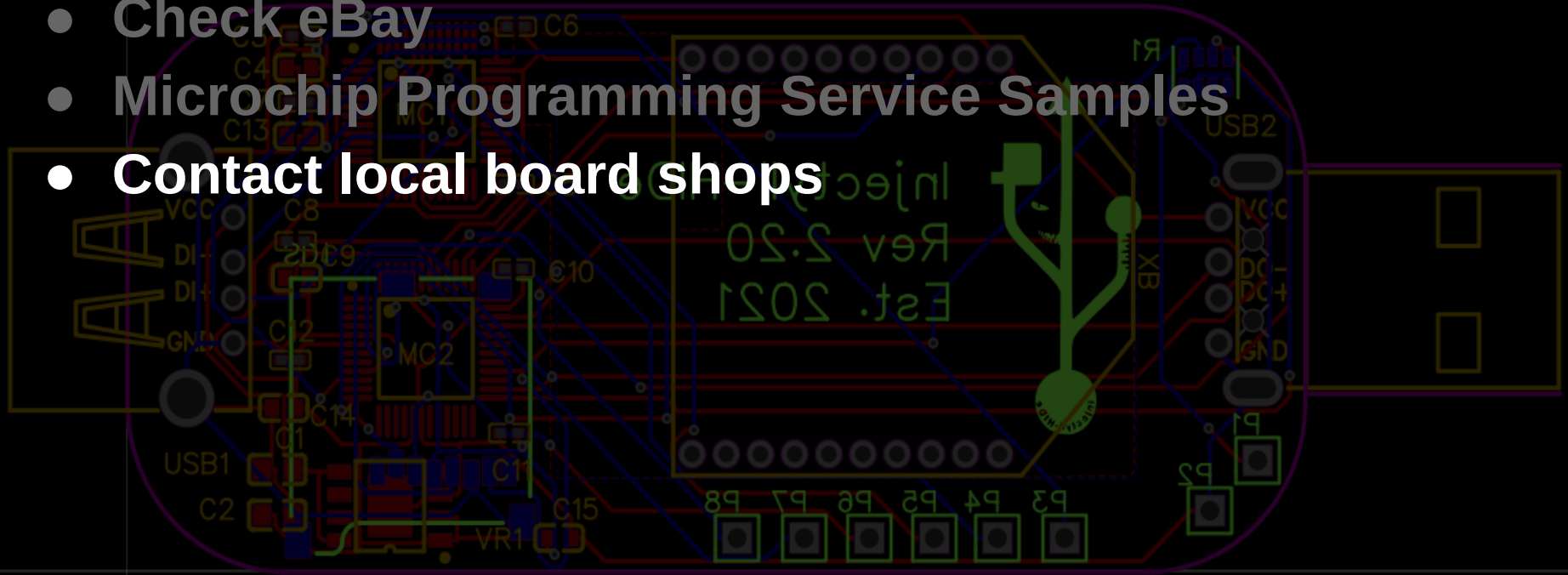
Navigating the Chip Shortage

- Check eBay
- **Microchip Programming Service Samples**



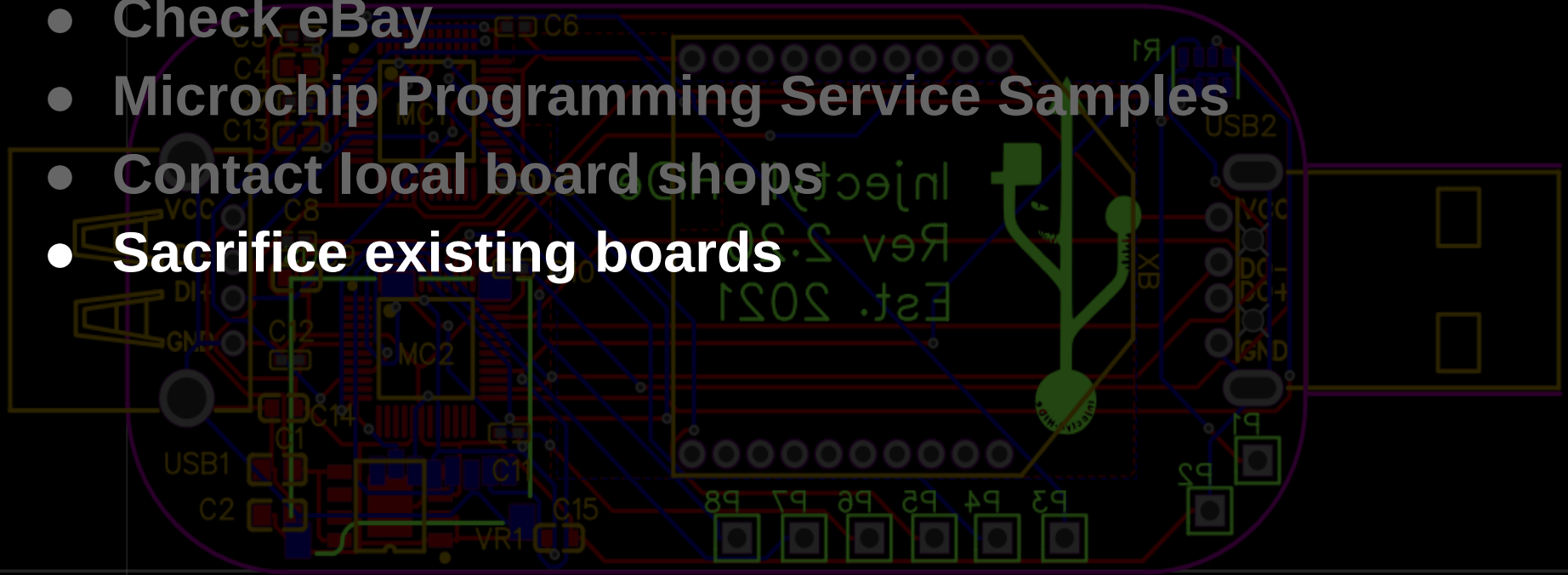
Navigating the Chip Shortage

- Check eBay
- Microchip Programming Service Samples
- **Contact local board shops**



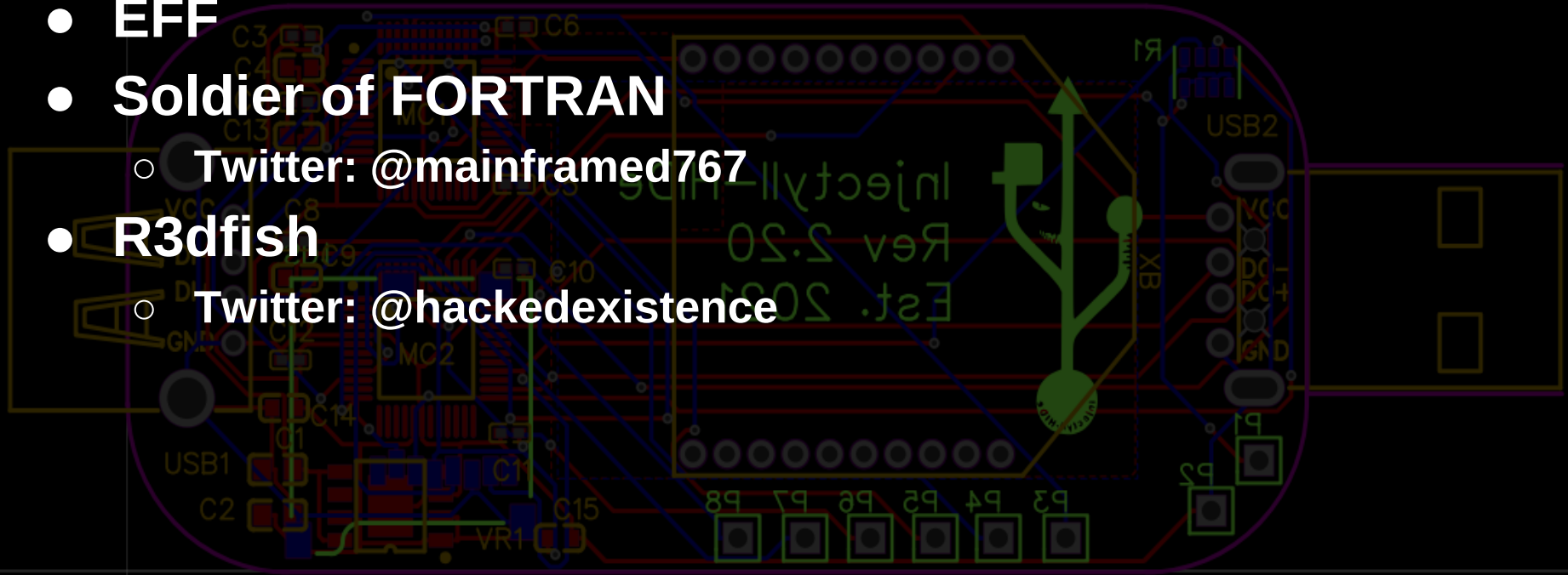
Navigating the Chip Shortage

- Check eBay
- Microchip Programming Service Samples
- Contact local board shops
- **Sacrifice existing boards**



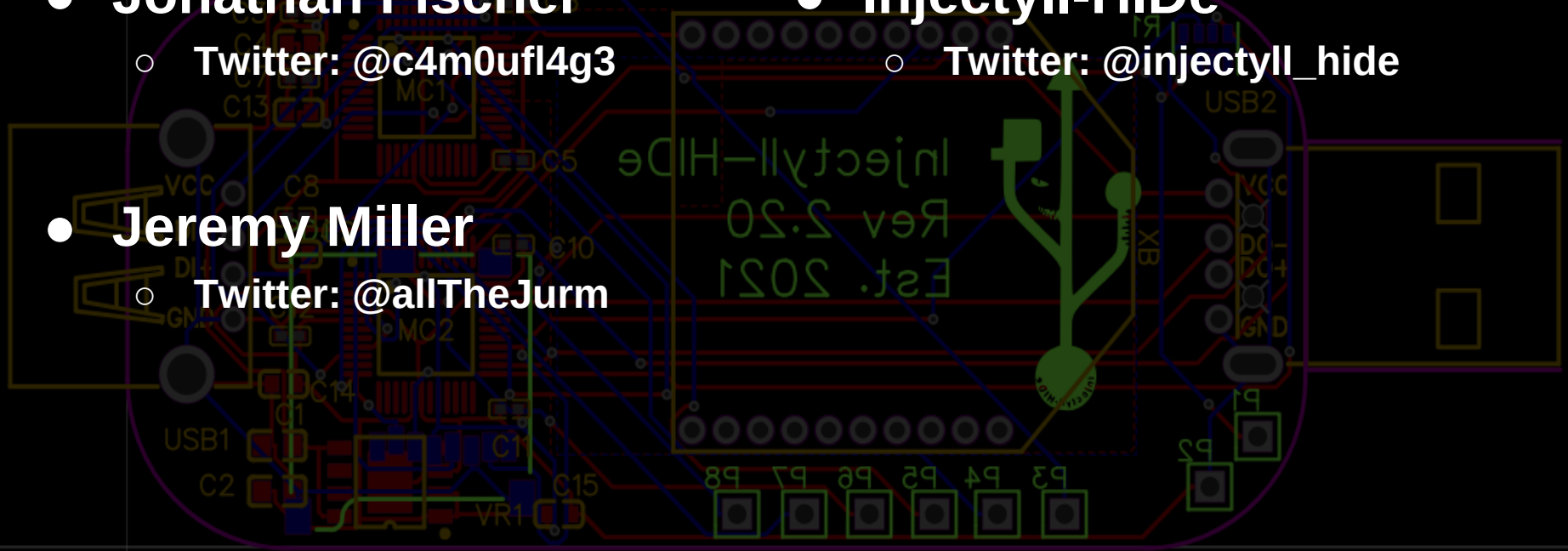
Special Thank You

- EFF
- Soldier of FORTRAN
  - Twitter: @mainframed767
- R3dfish
  - Twitter: @hackedexistence



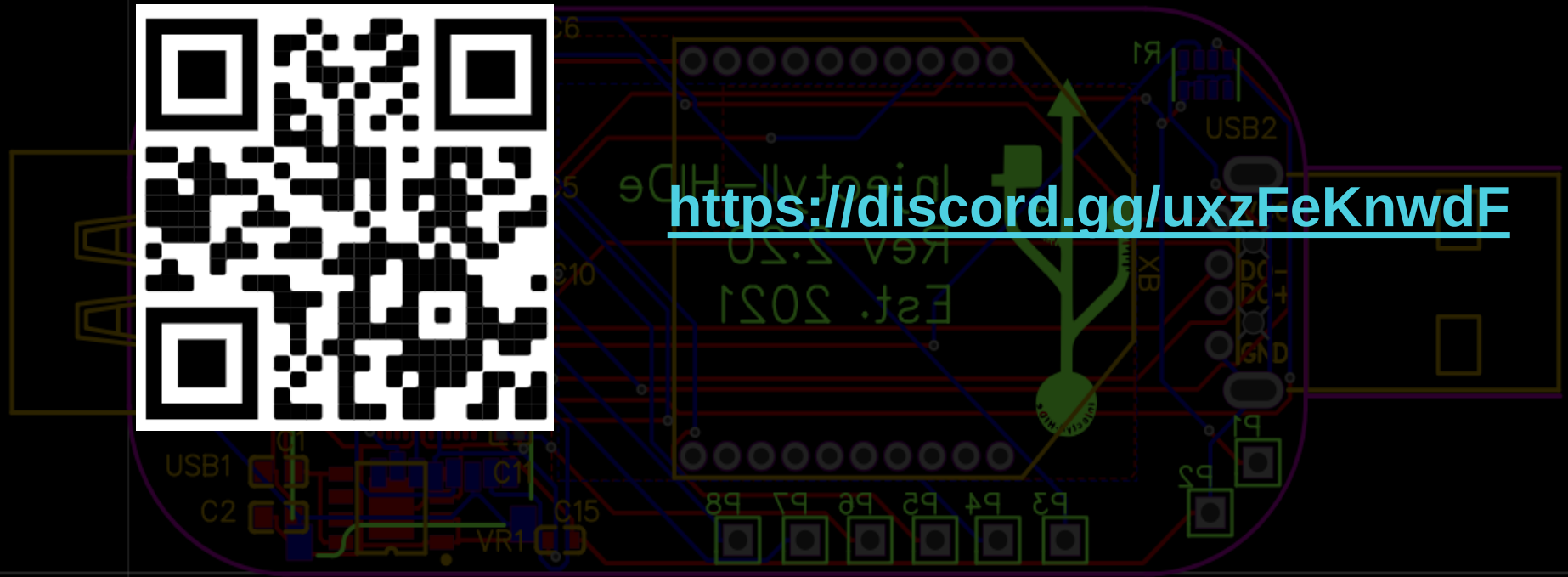
Contact Twitter

- **Jonathan Fischer**
  - **Twitter: @c4m0ufl4g3**
- **Jeremy Miller**
  - **Twitter: @allTheJurm**
- **Injectyll-HIDe**
  - **Twitter: @injectyll_hide**



Contact Discord

https://discord.gg/uxzFeKnwdF



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@Injectyll_HIDe

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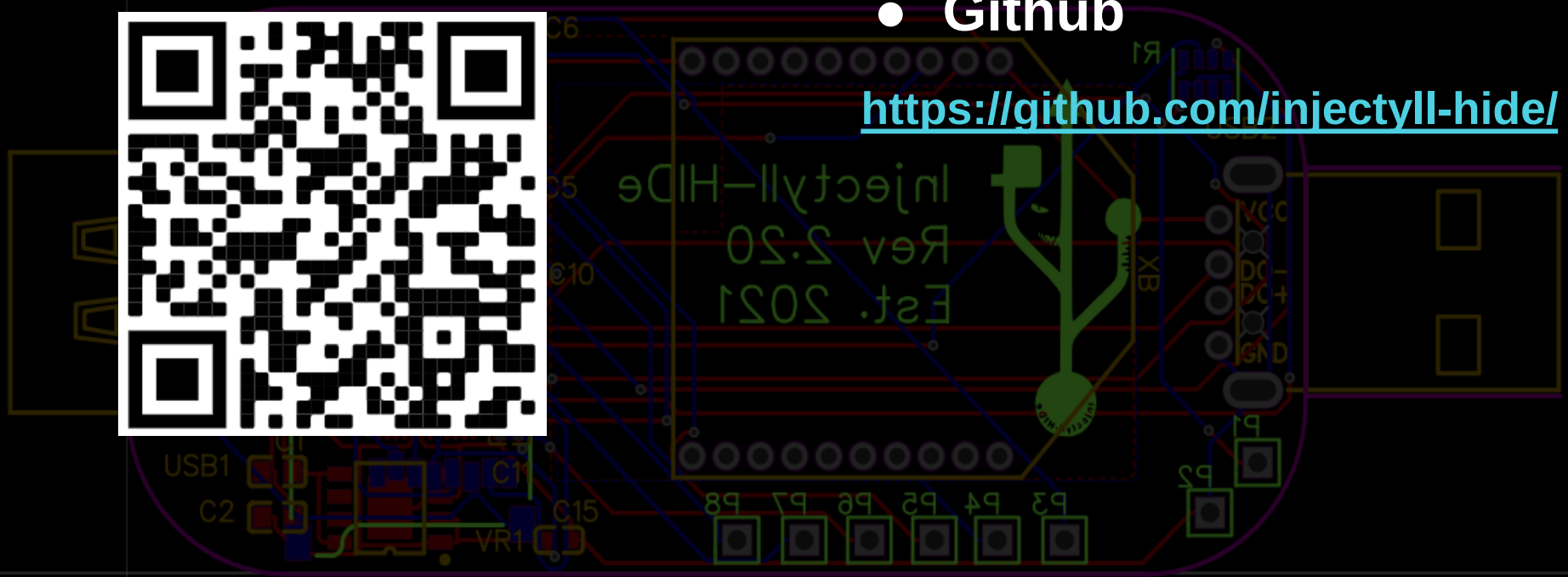
Contribute

- **Github**

https://github.com/injectyll-hide/



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