Project Description: Framework USB-C Emulation PCB for Raspberry Pi 5 Integration

This custom PCB is designed to mimic the performance of a Framework USB-C Expansion Card and bring it natively into a Raspberry Pi 5, breaking the native hardware limitations. Since the Framework Expansion Card is simply a passive controller (with no native Thunderbolt, DisplayPort, or USB role-switching capabilities), this board serves as an intermediary by handling and channeling signals in a smart, indirect way to emulate the sought-after performance.

The board perform three important tasks:

HDMI Video Output:
In place of using native USB-C DisplayPort Alt Mode (which the Raspberry Pi 5 doesn't support), the board takes a simple HDMI signal from the micro-HDMI port on the Pi and routes it to a full-size HDMI connector. That HDMI connector is routed and connected in such a manner that it aligns where the USB-C expansion card would otherwise provide video, sort of "simulating" the DisplayPort operation over a special HDMI connection.

Power Management with USB-C:
A USB-C input port, in conjunction with a USB Power Delivery (PD) sink controller, is utilized to negotiate power from an external power source. Power provided by it charges a lithium battery bank and distributes regulated power to the remainder of the system, including the Raspberry Pi. The USB-C port also emulates the charging behavior of a Framework card and acts as the primary charging intake of the deck.

Central Control and Power Routing:
Power controllers and routing logic embedded within control power and signal distribution on the board. They determine whether power is being delivered to or from the battery, power routing between devices, and correct passive signal routing between USB, HDMI, and power lines. This enacts an orchestrated, bidirectional system simulating operation of a fully functional USB-C Framework Expansion Card.

By replicating the fundamental behaviors of a Framework USB-C Expansion Card, without requiring native Thunderbolt or DisplayPort implementation, this board makes it possible for a Raspberry Pi 5 to integrate more naturally into a modular Framework-style system, with video output, USB connections, and smart power delivery being controlled via emulated control.

Components that are included as part of the PCB:

- Raspberry Pi 5 (8 GB)
- UGREEN 20000mAh 100W

- **Framework Expansion Card (USB-A)
- **Framework Expansion Card (USB-C)

**if you're still confused with what a framework expansion card does, please refer to https://github.com/FrameworkComputer/ExpansionCards

Symbols Included in the PCB

- Conn_02x20_Top_Bottom
- CH224K (For USB-C Connector)
- *12401610E4_2A (USB-C Receptacle)
- *MP1584EN (Buck Converter)
- HDMI Type A Female Connector
- *HD3SS215IRTQR (Texas Instruments)

**any symbol marked with a star is a custom symbol and footprint that I pulled from SnapEDA (https://www.snapeda.com/)

Power Symbols

- PTVS5V0Z1USK (Diode Cap)
- GND (Ground)
- FerriteBead
- USBLC6-2SC6 (Voltage Splitter)
- Capacitor (0.1 µF cap)
- +5V

Below is a pinout of all the components in my schematic. Please keep in mind that while you take a look at my schematic, if you're visibly disgusted with the work that I've done to the point where you want to make it yourself, I'm open to any honest constructive criticism. But other than that, Thank you for taking the time out of your day to review this pcb.

Framework USB-A Port

Function	From	Pin Name	To	Pin Name

Power	**J2**	**VBUS (Pin 9)**	**J6**	**VBUS_A (A9)**
Power	**J2**	**VBUS (Pin 10)**	**J6**	**VBUS_B (B9)**
Ground	**J2**	**GND (any)**	**J6**	**GND_A (A12)**
Ground	**J2**	**GND (any)**	**J6**	**GND_B (B12)**
Power	**J2**	**VBUS**	**U2 (CH224K)**	**Pin 8 (VBUS)**
Ground	**J2**	**GND**	**U2 (CH224K)**	**Pin 3 (GND)**
USB 2.0 Data	**J2**	**USB2_D+ (3)**	**J6**	**D1+ (A6)**
USB 2.0 Data	**J2**	**USB2_D− (4)**	**J6**	**D1− (A7)**
USB 2.0 Data	**J2**	**USB2_D+ (3)**	**J6**	**D2+ (B6)**
USB 2.0 Data	**J2**	**USB2_D− (4)**	**J6**	**D2− (B7)**
USB 2.0 Data	**J2**	**USB2_D+**	**U2 (CH224K)**	**Pin 4 (DP)**
USB 2.0 Data	**J2**	**USB2_D−**	**U2 (CH224K)**	**Pin 5 (DM)**
USB 3.0 TX	**J2**	**TX+ (5)**	**J6**	**TX1+ (A2)**
USB 3.0 TX	**J2**	**TX− (6)**	**J6**	**TX1− (A3)**
USB 3.0 RX	**J2**	**RX+ (7)**	**J6**	**RX2+ (A11)**
USB 3.0 RX	**J2**	**RX− (8)**	**J6**	**RX2− (A10)**
USB 3.0 TX	**J2**	**TX2+**	**J6**	**TX2+ (B2)**
USB 3.0 TX	**J2**	**TX2−**	**J6**	**TX2− (B3)**
USB 3.0 RX	**J2**	**RX1+**	**J6**	**RX1+ (B11)**
USB 3.0 RX	**J2**	**RX1−**	**J6**	**RX1− (B10)**
CFG Channel	**J6**	**CC1 (A5)**	**U2**	**Pin 7 (CC1)**
CFG Channel	**J6**	**CC2 (B5)**	**U2**	

Framework USB-C Port

Function	From Component	From Pin Name	To Component	To Pin Name
USB Power Input	J8	VBUS_A	U1	VBUS
USB Power Input	J8	VBUS_B	U1	VBUS
USB 2.0 Data	J8	D1+ (A6)	U1	DP
USB 2.0 Data	J8	D1− (A7)	U1	DM
USB 2.0 Data	J8	D2+ (B6)	U1	DP
USB 2.0 Data	J8	D2− (B7)	U1	DM
CC Configuration	J8	CC1 (A5)	U1	CC1
CC Configuration	J8	CC2 (B5)	U1	CC2
Ground	J8	GND_A	GND Plane	GND
Ground	J8	GND_B	GND Plane	GND
Shield	J8	SHIELD	GND Plane	SHIELD
Power Good Output	U1	PG	D4 (Zener)	ZD (to GND)
5V Output	U1	VBUS	HDMI Conn (J3)	VCC / 5V
Config Set	U1	CFG1	GND	GND
Config Set	U1	CFG2	GND	GND
Config Set	U1	CFG3	GND	GND
Logic Supply	U1	VDD	5V Rail	+5V
Ground	U1	GND	GND Plane	GND
High-Speed TX	J8	TX1+/−	U4	DDCx_C
High-Speed TX	J8	TX2+/−	U4	DDCx_C
High-Speed RX	J8	RX1+/−	U4	DDCx_A/B
High-Speed RX	J8	RX2+/−	U4	DDCx_A/B
HDMI Output Select	MCU/GPIO	AUX_SEL	U4	AUX_SEL

HDMI Output Enable	**MCU/GPIO**	**OE**	**U4**	**OE**
HDMI Clock Select	**MCU/GPIO**	**Dx_SEL**	**U4**	**Dx_SEL**
HDMI Switch Power	**5V Rail**	**+5V**	**U4**	**VDD**
HDMI Switch Ground	**GND**	**GND**	**U4**	**GND**
ESD Protection	**J8**	**D+/−**	**D3 (TVS)**	
HDMI Conn Power	**5V Rail**	**+5V**	**J3**	**VCC / +5V**
HDMI Conn Data	**U4**	**HDMI Pairs**	**J3**	**HDMI Pairs**
HDMI Ground	**GND**		**J3**	**GND**
HDMI Shield	**GND**	**Shield**	**J3**	**SH**
HDMI Clock/Data Pair	**U4**	**D2+**	**J3**	**D2+**
HDMI Clock/Data Pair	**U4**	**D2−**	**J3**	**D2−**
HDMI Data	**U4**	**D1+**	**J3**	**D1+**
HDMI Data	**U4**	**D1−**	**J3**	**D1−**
HDMI Data	**U4**	**D0+**	**J3**	**D0+**
HDMI Data	**U4**	**D0−**	**J3**	**D0−**
HDMI Clock	**U4**	**CK+**	**J3**	**CK+**
HDMI Clock	**U4**	**CK−**	**J3**	**CK−**
HDMI CEC	**Optional**	**CEC**	**J3**	**CEC**
HDMI SCL	**U4**	**SCL**	**J3**	**SCL**
HDMI SDA	**U4**	**SDA**	**J3**	**SDA**
Hot Plug Detect	**J3**	**HPD**		**Not Connected**
HDMI GND	**GND**	**GND**	**J3**	**GND**

Battery Bank (from Power bank to RP5 and PCB)

From Component / Port	Pin / Signal	To Component / Port	Pin / Signal	Notes
Battery Pack	**+7.4 V**	**MP1584EN**	**VIN**	**Buck converter input**
Battery Pack	**+7.4 V**	**CH224K**	**VBUS (Pin 10)**	**Required for PD negotiation**
Battery Pack	**GND**	**MP1584EN**	**GND**	**Common ground**
Battery Pack	**GND**	**CH224K**	**GND (Pin 9)**	**Common ground**
Battery Pack	**GND**	**Framework Expansion Card**	**GND**	**All GNDs must be tied together**
MP1584EN	**VOUT (5 V)**	**Framework Expansion Card**	**VBUS (Pins A4, B4)**	**Feeds regulated 5 V to USB-C connector**
CH224K	**CC1 (Pin 2)**	**Framework Expansion Card**	**CC1 (Pin A5)**	**PD trigger and negotiation**
CH224K	**CC2 (Pin 3)**	**Framework Expansion Card**	**CC2 (Pin B5)**	**Optional—only one CC typically needed**
CH224K	**DP/DM (Pins 6/7)**	**Framework Expansion Card**	**USB2 D+/D− (A6/A7 or B6/B7)**	**Optional—USB 2.0 data passthrough**
Framework Expansion Card	**USB-C Connector**	**Raspberry Pi 5**	**USB-C Power Port**	**Power and optional data via USB-C cable**
Framework Expansion Card	**TX1+ / TX1− (A2 / A3)**	**Raspberry Pi 5**	**USB 3.0 TX**	**For USB 3.0 transmission**

Framework Expansion Card	**RX1+ / RX1−** **(B2 / B3)**	**Raspberry Pi 5**	**USB 3.0 RX**	**For USB 3.0 reception**