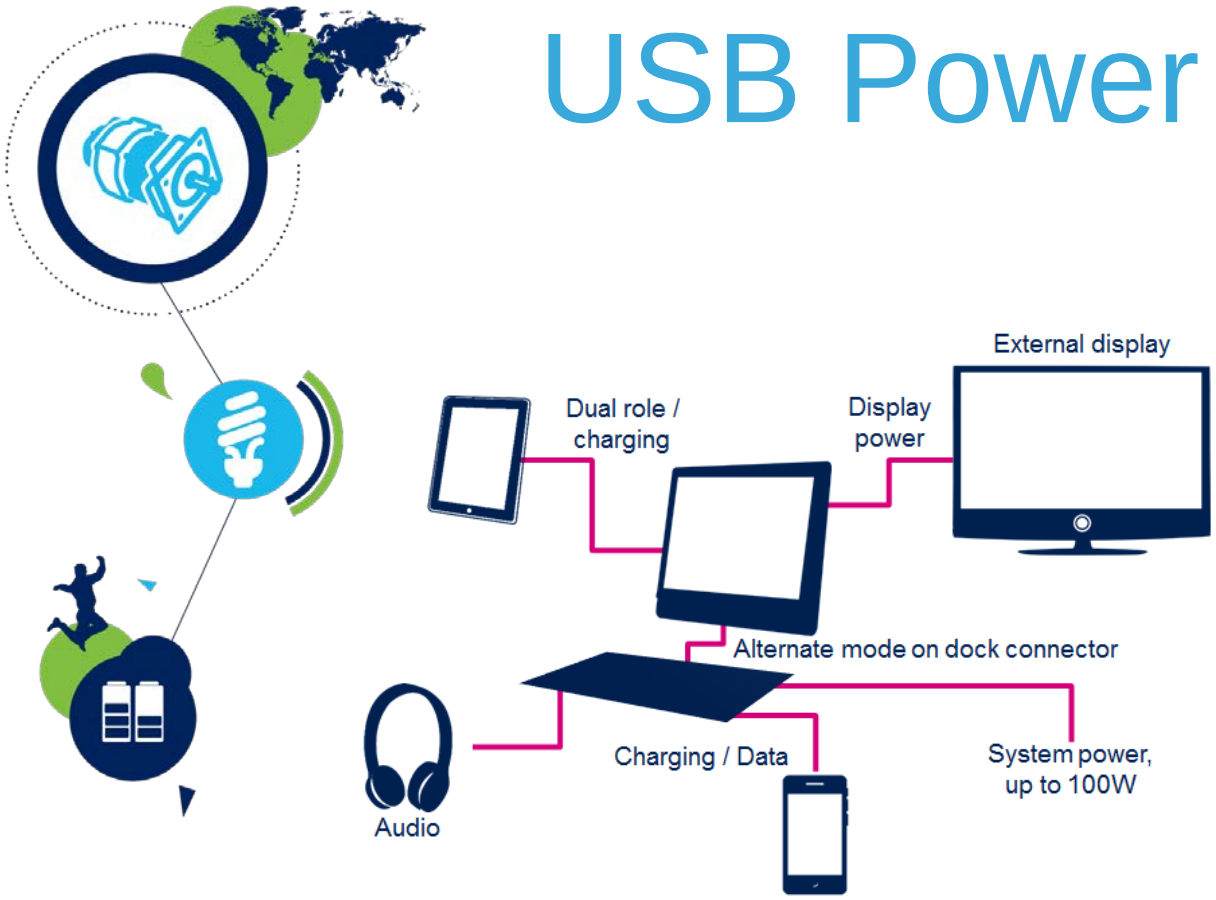
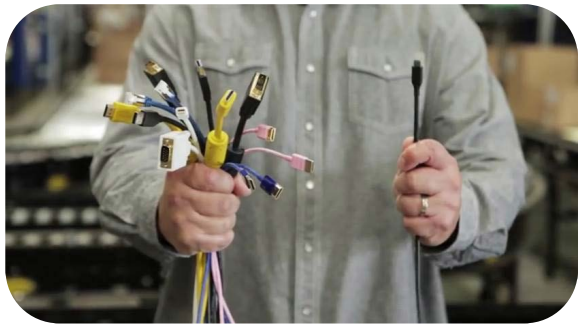
USB Power Delivery and Type-C





Overview

Architecture

Product Portfolio

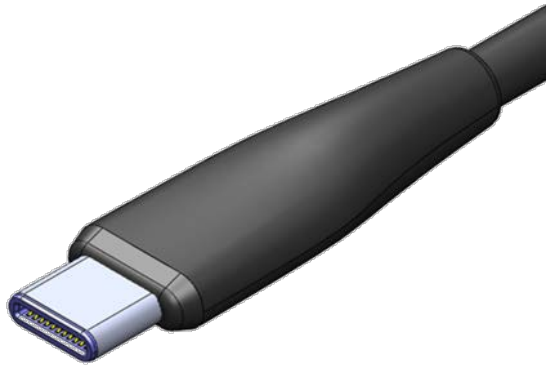
Solution

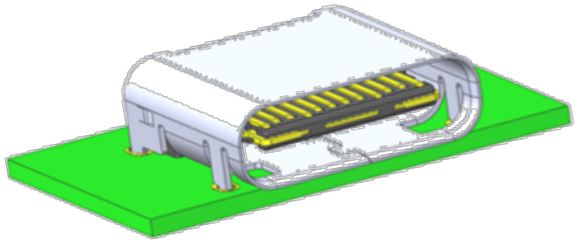
life.augmented

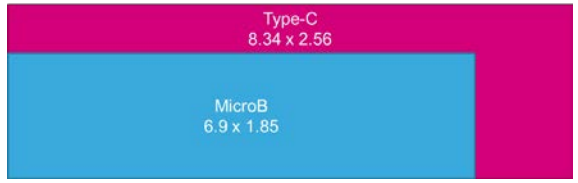
USB Type-C Overview

USB Power Delivery specification introduces USB Type-C receptacle, plug and cable; they provide a smaller, thinner and more robust alternative to existing USB interconnect. Main features are:

- Enable new and exciting host and device form-factors where size, industrial design and style are important parameters
- Work seamlessly with existing USB host and device silicon solutions
- Enhance ease of use for connecting USB devices with a focus on minimizing user confusion for plug and cable orientation







life.augmented

USB Type-C Overview

Type-C Features

- Enable **new** and exciting host and device **form-factors** where size, industrial design and style are important parameters
- Work **seamlessly with existing USB** host and device silicon solutions
- **Enhance ease of use** for connecting USB devices with a focus on **minimizing user confusion** for plug and cable orientation
- Simple Power Delivery implementation (BMC)

Mode of Operation	Nominal Voltage	Maximum Current	Notes
USB 2.0	5 V	500 mA	Default current, based on definitions in the base specifications
USB 3.1	5 V	900 mA	
USB BC 1.2	5 V	Up to 1.5 A	Legacy charging
USB Type-C @ 1.5 A	5 V	1.5 A	Supports high power devices
USB Type-C @ 3.0 A	5 V	3 A	Supports higher power devices
USB PD	Configurable up to 20 V	Configurable up to 5 A	Directional control and power level management

life.augmented

The Re-Evolution of USB

USB has evolved from a data interface capable of supplying limited power to a primary provider of *power* with a data interface

Power Delivery	More **Power** with USB Power Delivery (100W)
Type-C	More **Flexibility** with a new reversible USB-C connector
Alternate Mode	More **Protocols** (Display Port, HDMI, VGA, Ethernet…)
USB IF	More Speed with USB 3.1 (10 Gbit/s)

life.augmented

USB PD → Power Profiles

as of today …. per USB PD release 2.0

Source capabilities organized as profiles

	PROFILE 0 Reserved	
Hand-held devices, today's peripherals	PROFILE 1 5V @ 2A	10W Default start-up profile
Tablets, netbooks, most peripherals	PROFILE 2 5V @ 2A, 12V @ 1.5A	18W
Thinner notebooks, larger peripherals	PROFILE 3 5V @ 2A, 12V @ 3A	36W
Larger notebooks, hubs, docks	PROFILE 4 5V @ 2A, 12V, 20V @ 3A	60W Limit for Micro-B/AB connector
Workstations, hubs, docks	PROFILE 5 5V @ 2A, 12V, 20V @ 5A	100W Limit for Standard A/B connector

- Additional capabilities possible as optional extensions to standard pr

life.augmented

USB PD → New Profiles proposal

Power Adapter Examples

	Permitted		Not permitted
	Standard	*Include optionality(1)*	
"15 W"	5 V @ 3 A (15 W)	5 V @ 3 A (15 W) 8 V @ 1.8 A (15 W)	5 V @ 2 A (10 W) 8 V @ 1.8 A (15 W)
"27 W"	5 V @ 3 A (15 W) 9 V @ 3 A (27 W)	5 V @ 3 A (15 W) 9 V @ 3 A (27 W) 12 V @ 2.25 A (27 W)	5 V @ 3 A (15 W) 9 V @ 3 A (27 W) 12 V @ 3 A (36 W)
"45 W"	5 V @ 3 A (15 W) 9 V @ 3 A (27 W) 15 V @ 3 A (45 W)	5 V @ 3 A (15 W) 9 V @ 3 A (27 W) 15 V @ 3 A (45 W) 16 V @ 2.8 A (45 W)	5 V @ 3 A (15 W) 9 V @ 3 A (27 W) X 16 V @ 2.8 A (45 W)
"60 W"	5 V @ 3 A (15 W) 9 V @ 3 A (27 W) 15 V @ 3 A (45 W) 20 V @ 3 A (60 W)	5 V @ 3 A (15 W) 9 V @ 3 A (27 W) 15 V @ 4 A (60 W) 20 V @ 3 A (60 W)	5 V @ 3 A (15 W) 9 V @ 3 A (27 W) 15 V @ 5 A (75 W) 20 V @ 3 A (60 W)

(1) Making use of optionality is not encouraged as it diminishes interoperability – should only be utilized in specific use cases where a local optimization is of value and the standard voltages are still supported by Source & Sink

Type-C Pin Outs Functions

Receptacle

High Speed Data Path (RX for USB 3.1, or reconfigured in Alternate Mode)

USB 2.0 Interface

High Speed Data Path (TX for USB 3.1, or reconfigured in Alternate Mode)

A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A12	A12
GND	TX1+	TX1-	V_{BUS}	CC1	D+	D-	SBU1	V_{BUS}	RX2-	RX2+	GND
GND	RX1+	RX1-	V_{BUS}	SBU2	D-	D+	CC2	V_{BUS}	TX2-	TX2+	GND
B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1

Secondary Bus

Cable Bus Power

Cable Ground

Configuration Channel

Two pins on the USB Type-C receptacle, CC1 and CC2, are used in the discovery, configuration and management of connections across USB type-C cable

life.augmented

Type-C Pin Outs Functions

Plug

High Speed Data Path (RX for USB 3.1, or reconfigured in Alternate Mode)

USB 2.0 Interface

High Speed Data Path (TX for USB 3.1, or reconfigured in Alternate Mode)

A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1
GND	RX2+	RX2-	V_{BUS}	SBU1	D-	D+	CC	V_{BUS}	TX1-	TX1+	GND
GND	TX2+	TX2-	V_{BUS}	V_{CONN}			SBU2	V_{BUS}	RX1-	RX1+	GND
B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12

Secondary Bus

Cable Bus Power

Cable Ground

Configuration Channel

On a standard USB Type-C cable, only a single CC wire within each plug is connected through the cable to establish signal orientation

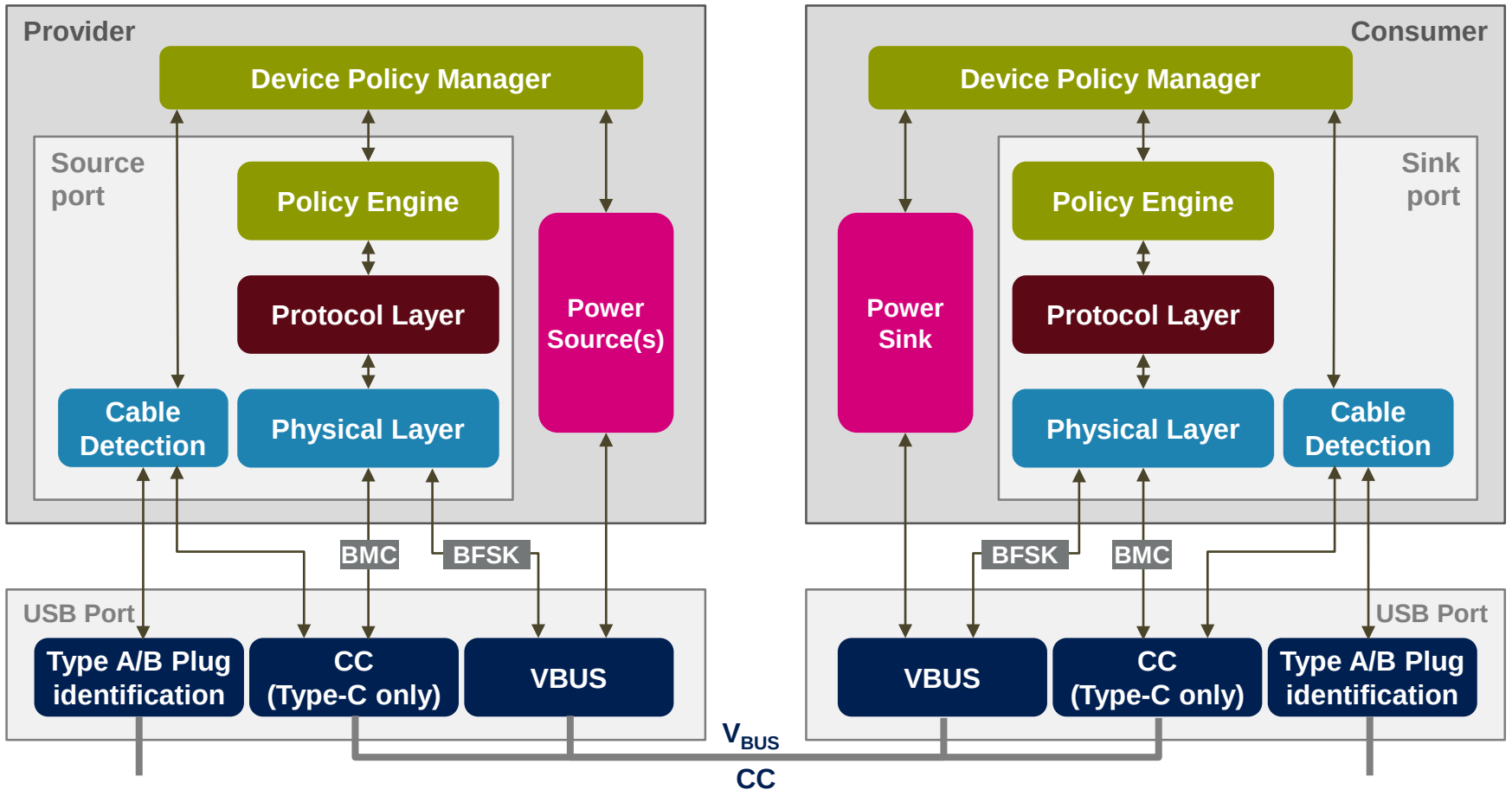
The other CC pin is repurposed as V_{CONN} for powering electronics

Also, only one set of USB 2.0 D+/D- wires are implemented

life.augmented

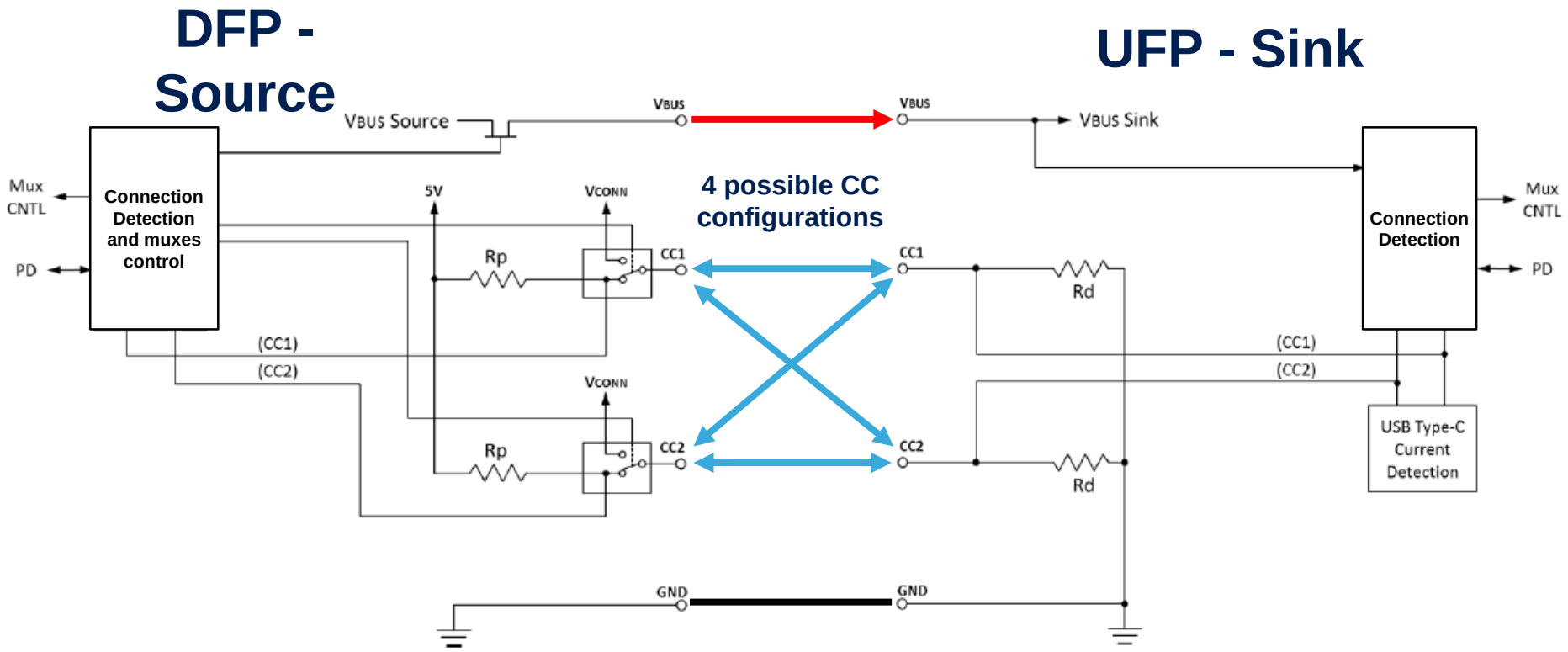
Architecture

Architecture and key words



Communication across the channel uses Biphase Mark Coding (BMC) over CC in Type C connector

USB Type-C CC Connections



- Detect attach/detach of USB ports, e.g. a DFP to a UFP
- **Resolve cable orientation and twist connections** to establish USB data bus routing
- Establish DFP and UFP roles between two attached ports
- Discover and configure VBUS
- USB Power Delivery Communication

life.augmented

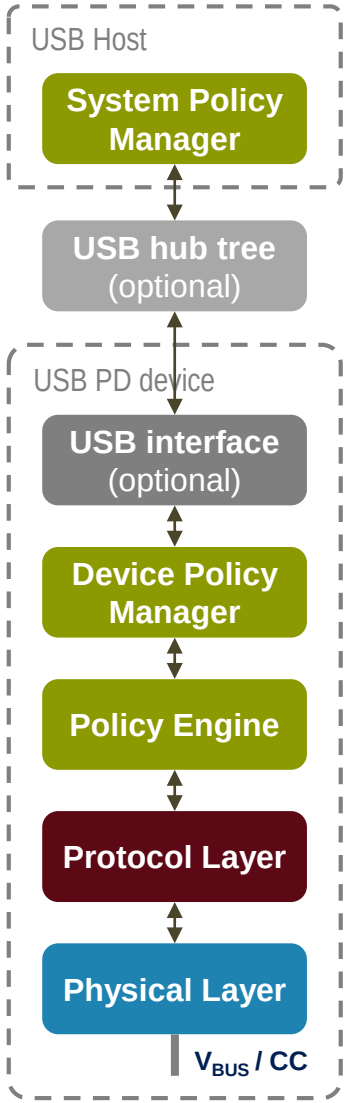
USB PD Stack & Policy

Policies

System Policy Manager (system wide) is optional. It monitors and controls System Policy between various Providers and Consumers connected via USB.

Device Policy Manager (one per Provider or Consumer) provides mechanisms to monitor and control the USB-PD within a particular Provider or Consumer. It enables local policies to be enforced across the system by communication with the System Policy Manager.

Policy Engine (one per Source or Sink Port) interacts directly with the Device Policy Manager in order to determine the present local policy to be enforced.



Protocol Layer

The Protocol Layer forms the messages used to communicate information between a pair of ports. It receives inputs from the Policy Engine indicating which messages to send and indicates the responses back to the Policy Engine

Physical Layer

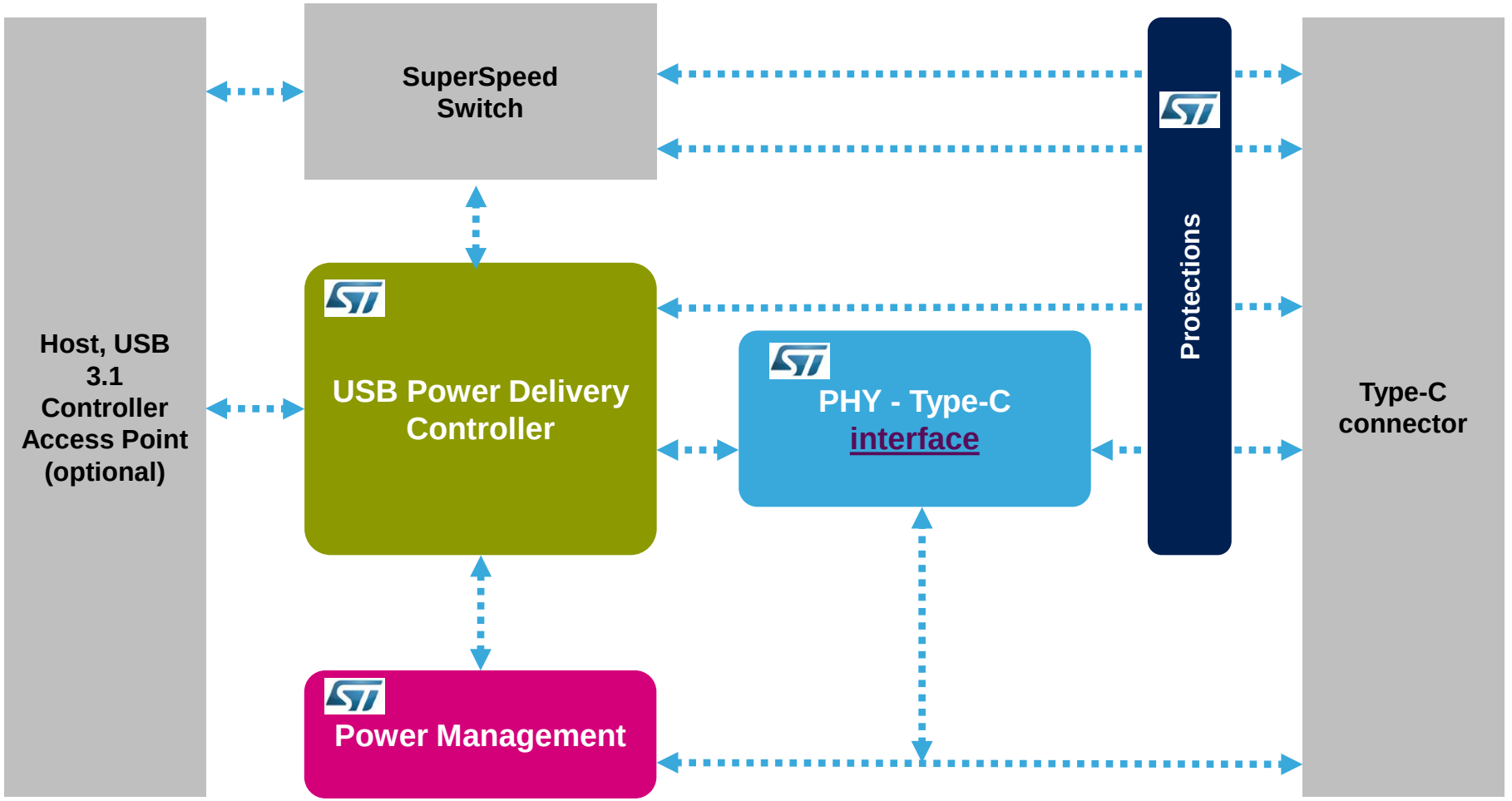
It is responsible for sending and receiving messages across either the V_{BUS} or CC wire. It consists of a transceiver that superimposes a signal (BFSK on V_{BUS} or BMC on CC) on the wire.

It is responsible for managing data on the wire and for collision avoidance and detects errors in the messages using a CRC

life.augmented

Product Portfolio

A complete offer to “lean in” USB PD Ecosystem



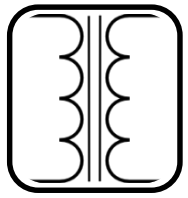
life.augmented

Profile 1-2-3
Power Source Building Blocks

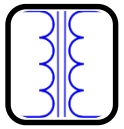
High Voltage

Flyback Controller: STCH02

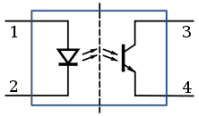
Power MOSFET



main transformer



pulse transformer



optocoupler

communication

Low Voltage

Rectifier

CC/CV SEA01

Feedback Network Selection

USB PD Interface IC

Multi Port case: Post regulation for each port

DC/DC Post regulation

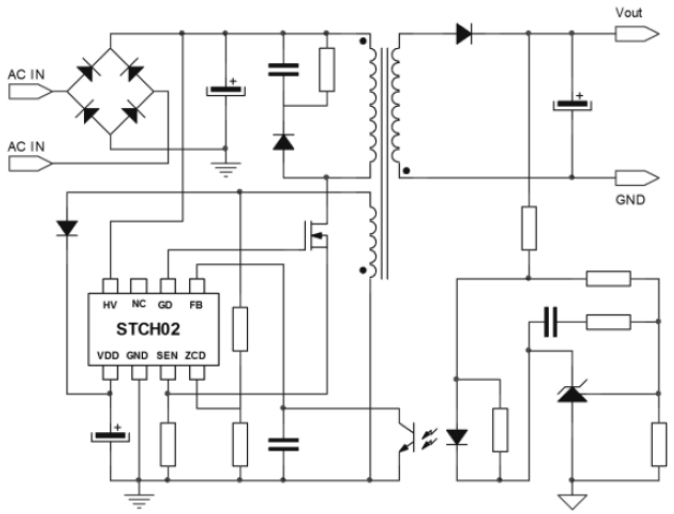
USB PD Interface IC

- *It covers profile 1-2-3 from 5W to 45W*
- *High Efficiency*
- *Low EMI design: intelligent Jitter for EMI suppression*

life.augmented

STCH02

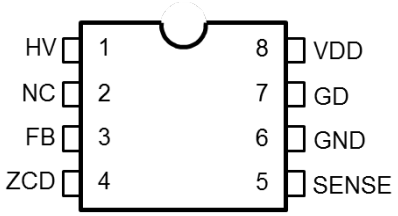
Primary Side Controller: Adapters up to 45W



Features

- Proprietary Constant current output regulation (CC) with no opto-coupler
- 700V embedded HV start-up circuit
- Quasi-resonant (QR) Zero Voltage Switching (ZVS) operation
- Valley skipping at medium-light load and advanced burst mode operation at no-load for under 10mW consumption
- Accurate adjustable output OVP

e.s. available



SO8

Benefits

- Low part count. BOM reduction thanks to an extensive features integration
- Exceeding 5 stars: No-Load power < 10mW
  - HV start-up zero power consumption
  - Advanced burst-mode operation
- Flexibility: suitable for adapters from 5W to 40W
- High Efficiency
- Low EMI design: intelligent jitter for EMI suppression

life.augmented

Profile 4, 5

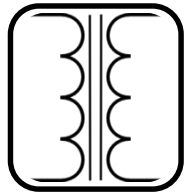
Power Source Building Blocks

High Voltage

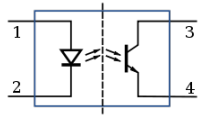
PFC
L6563H

LLC
L6699

Power
MOSFET



main
transformer



optocoupler

PFC-LLC
Integrated
New
solution
STCMB1

Low Voltage

Synchrounous
Rectification
SRK2001

Power MOSFET

CC/CV
SEA01

Post Regulation

DC/DC
Post regulation

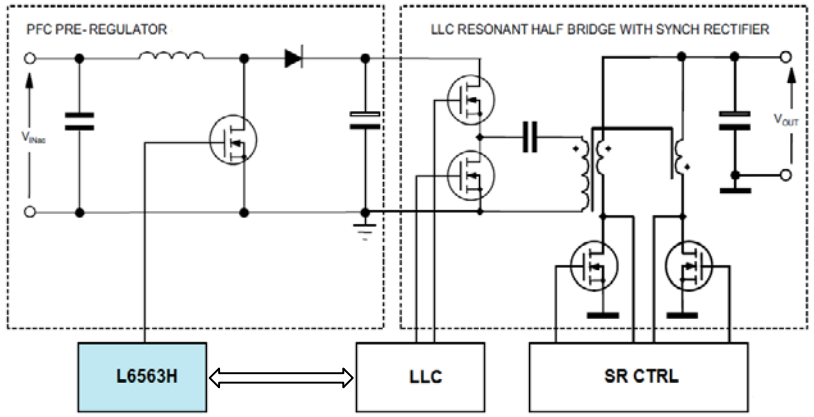
USB PD
Interface IC

1 per port

life.augmented

L6563H

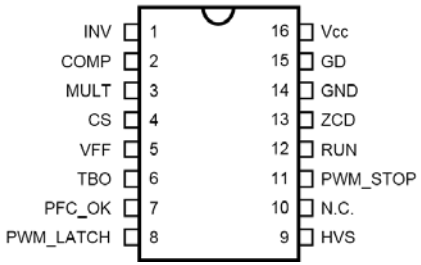
Transition Mode PFC controller



Features

- 700V High Voltage Start-up circuit
- Fast bidirectional input voltage feedforward
- Adjustable OVP
- AC Brownout Detection
- Tracking boost function
- Inductor saturation protection
- Proprietary THD optimizer circuit
- Interface for cascaded converters
- -600mA/+800mA gate driver

Datasheet : available on www.st.com



SO16

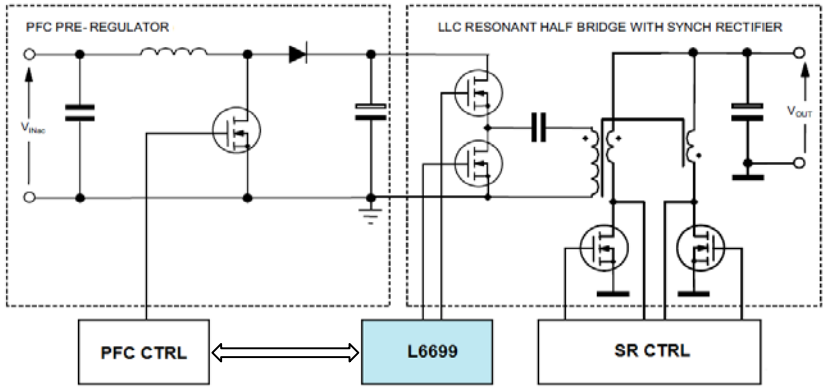
- Low steady state ripple and current distortion with limited undershoot or overshoot of the pre-regulator's output thanks to new input voltage feed-forward implementation
- Reduced THD of the current
- High reliability thanks to a full set of protections
- HV start-up significantly reduces consumption compared to standard discrete circuit solutions
- Facilitated cooperation with cascaded DC-DC converter thanks to several power management & housekeeping functions

life.augmented

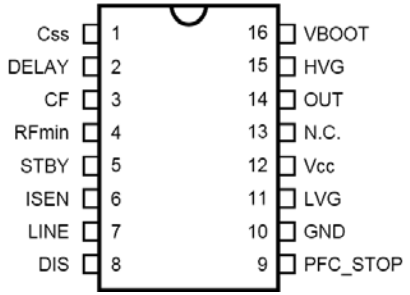
L6699

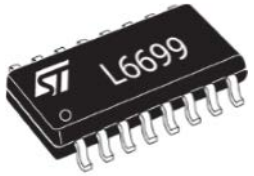
High power adapters 90W to 250W

Series-resonant half-bridge topology



Datasheet : available on www.st.com





SO16N

Features

- Self adjusting adaptive dead time
- Anti-capacitive mode protection
- Two-level OCP
  - Frequency shift
  - Immediate shutdown
- Safe-start procedure
- Burst-mode operation at light load
- Brown-out protection
- Interface with PFC controller

Benefits

- High efficiency:
  - Reduced internal consumption (Iq=1mA)
  - Adaptive dead time allows design optimization to achieve ZVS with lower magnetizing current
- Improved reliability and lifetime thanks to anti-capacitive protection and smooth start-up circuit
- Reduced audible noise when entering burst-mode operation thanks to smooth restart feature

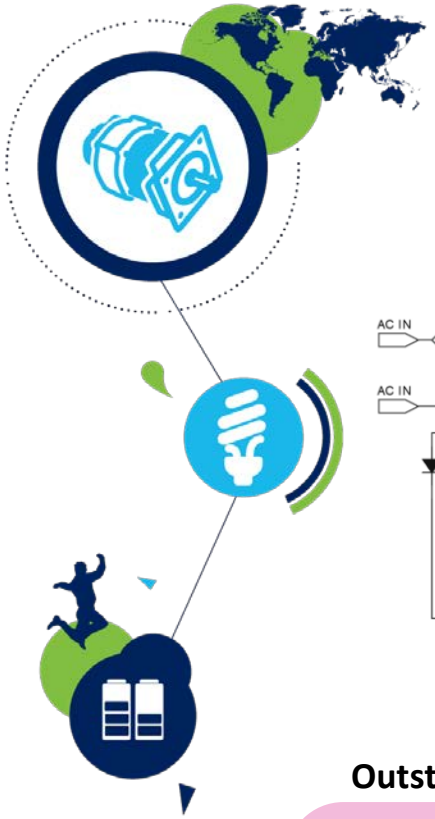
life.augmented

USB-PD
Power MOSFET product families

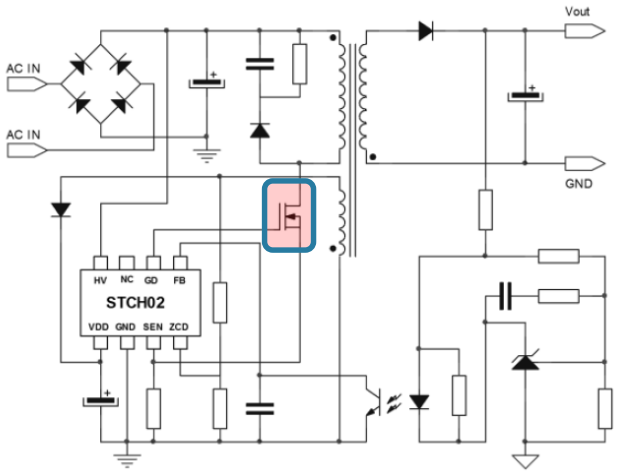
800V-1500V	600V-650V		40-120V
K5	M2	M6	F7
	Price/Performance	Premium efficiency	
Flyback	Flyback/PFC/LLC		Synch Rec

life.augmented

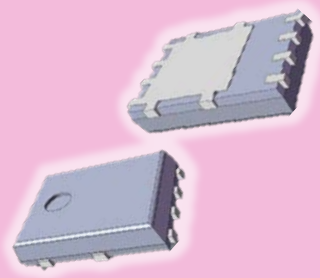
VHV PowerMOSFETs



Flyback Architecture



Outstanding Form Factor



STL8N80K5

800V, 950mOhm, 13nC
PowerFLAT5x6

Features

- Unmatched $R_{DS(on)}$ at very high BVDSS 800-950V-1050V
- Ultra-Low Q_G and high switching speed
- Extremely low thermal resistance
- High quality & reliability

Benefits

- Lower on-state conduction losses
- Best switching losses
- High efficiency with lower design complexity
- Ultra small Form factor

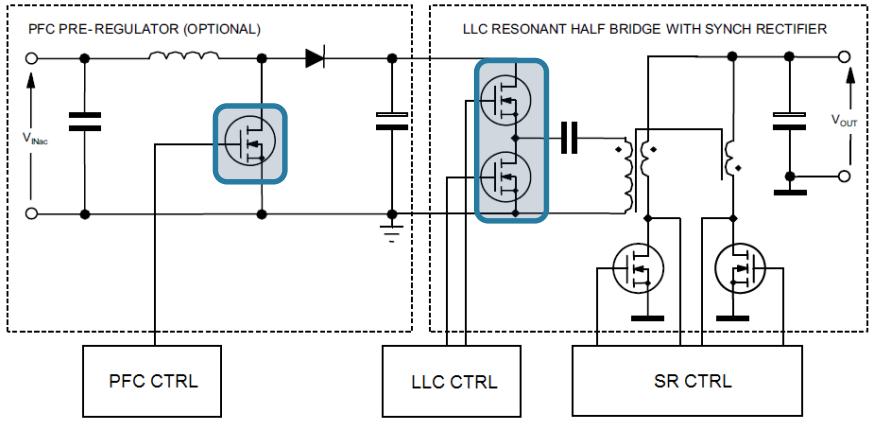
Product range example

Part Number	B_{VDss}	$R_{DS(on)}$	I_D
STB13N80K5	800V	0.45Ω	12A
STD8N80K5	800V	0.95Ω	6A
STD9N80K5	800V	0.90Ω	7A

life.augmented

Power MOSFET

PFC & LLC Architecture



Product range example

PFC	V_{DSS}	$R_{DS(on)}$	I_D
STF24N60M2	600V	0.190Ω	18A
STF25N60M2-EP	600V	0.188Ω	18A
STF20N60M2-EP	600V	0.278Ω	13A

PFC Performance

LLC	V_{DSS}	$R_{DS(on)}$	I_D
STF9N60M2	600V	0.750Ω	5.5A
STF15N60M2-EP	600V	0.378Ω	11A
STFI11N60M2-EP (e.s.available)	600V	0.595Ω	8.0A

LLC Performance

LLC	V_{DSS}	$R_{DS(on)}$	I_D
STF9N60M6	600V	0.750Ω	ES April '16
STF10N60M6	600V	0.600Ω	ES April '16
STF13N60M6	600V	0.380Ω	ES April '16

LLC Premium

Features

- Up to 30% lower Q_G vs main competition (equivalent die size)
- 400 – 700V BV_{DSS} rated
- Back-to-Back G-S Zener protected

Benefits

- Reduced switching losses
- Enhanced immunity vs ESD & Vgs spikes
- Technologies dedicated to specific topology

Product range example

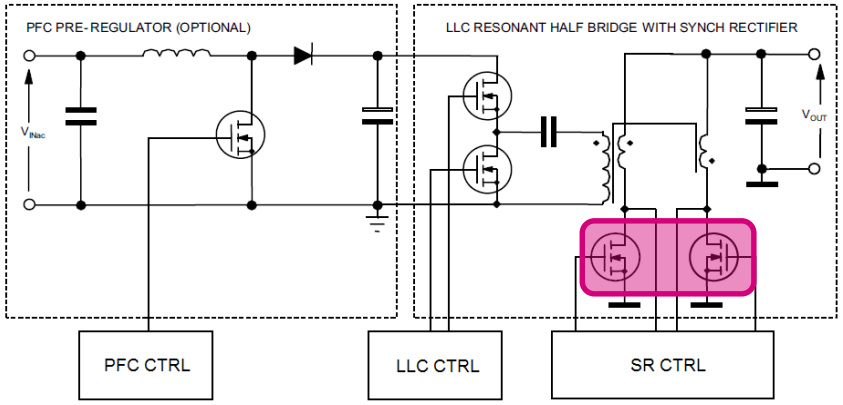
STL24N60M2

600V, 210mΩ, 28nC
PowerFLAT8x8

life.augmented

Power MOSFETs

Synchronous Rectification



Features

- Very low $R_{DS(on)}$;
- Proper C_{OSS};
- Low V_{SD} and Q_{RR} with soft recovery body-drain diode
- LL Vth

Part Number	Voltage	Ron	Current
STL260N4LF7	40V	<1.1mΩ	5.5A
STL200N45LF7	40V	<1.8mΩ	11A

Benefits

- Efficiency improvement due low conduction losses and to static and dynamic diode ones, minimized switching noise and Vds spike at turn OFF
- Easy driving features

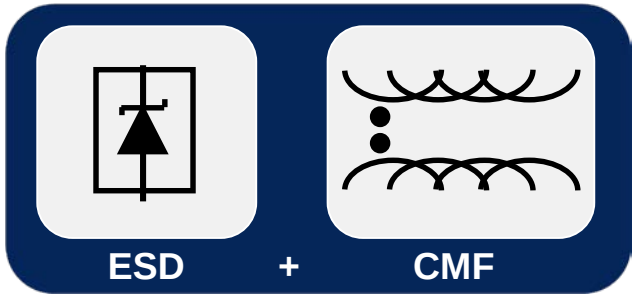
life.augmented

Protections

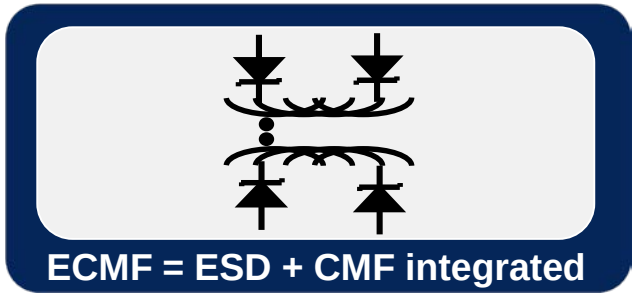
ESD/CMF/ECMF

High flexibility for the Designers needs to find best compatibilities

- Robustness: Surge capability up to 25kV and low clamping
- Flexibility & Integration: Single or multi lines products
- Transparency: High bandwidth for high speed signals



- High quality of protection
- Unique filtering shape capabilities
- Serial Interface: USB2.0/3.0, MIPI,DP, HDMI
- Filters radiated noise and limits antenna de-sense.



- High quality of protection
- High integration: 1mm2 / 2 differential lines
- Serial Interface: USB2.0/3.0, MIPI,DP, HDMI
- Filters radiated noise and limits antenna de-sense

life.augmented

Controller & Interface

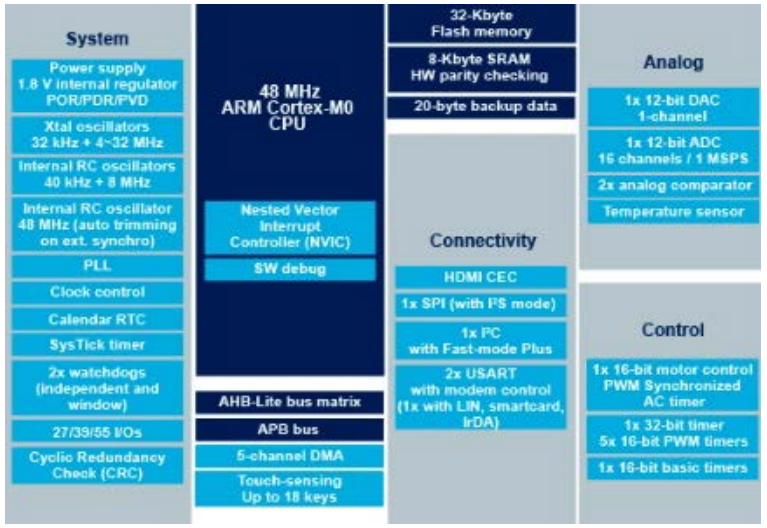
Value proposition: offer flexible and scalable solutions for designers

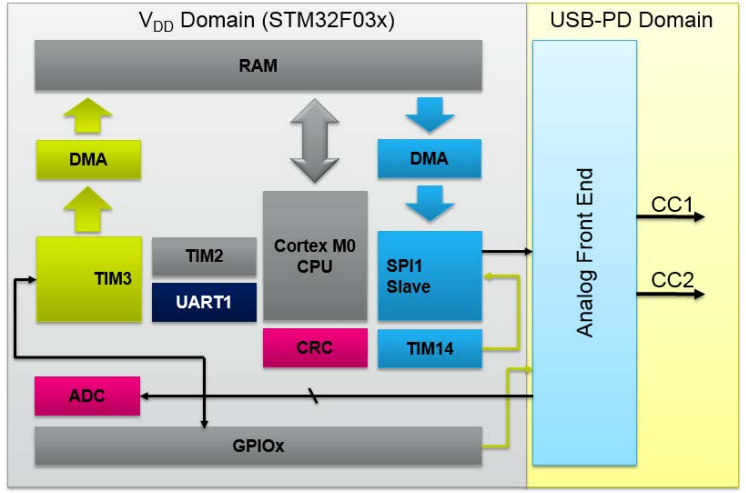
USB PD Controller MCU Based	PHY -Type-C Interface	USB PD Hard Coded Controller
STM32	STUSB16	STUSB4x
• FW USB PD Stack • Adaptability versus USB PD specification new release • PHY-Type-C interface companion chip • Market proven solution	• Dual Role Type-C Interface with BMC • Dual role capability • Configurable start-up profiles • Interface with external MCU through I^2C • Accessory support	• HW USB PD Stack • Flexible HW-SW partitioning • Autorun or Micro based • Easy Dead Battery Support • P2P with PHY-Type-C interface

life.augmented

MCU Overview:

STM32F0 HW resources





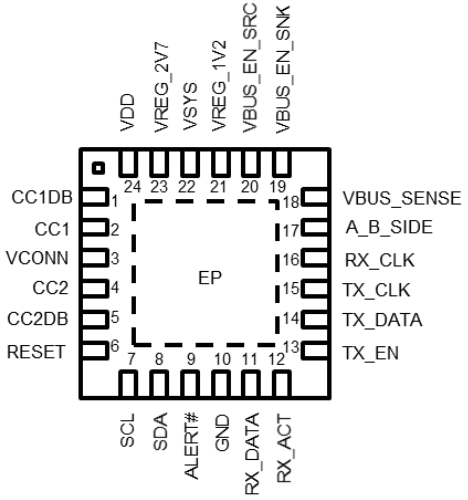
- Transmission uses : **TIM14, SPI1, DMA, GPIO**
- Reception uses : **TIM3, DMA, 1 comparator**
- **TIM2** is used to time-schedule tasks
- Embedded **ADC** to detect device on the CC bus and perform power measurements
- **CRC** to evaluate message's CRC
- Standard GP I/Os to control Vconn, Load switch, Vbus discharge switch, Vout selection (primary feedback…

Project	Flash Memory	RAM Memory
Provider only	25.5 kB	4.4 kB
Provider only (RTOS)	29.0 kB	7.3 kB
Provider/Consumer DRP (RTOS)	30.2 kB	7.3 kB

life.augmented

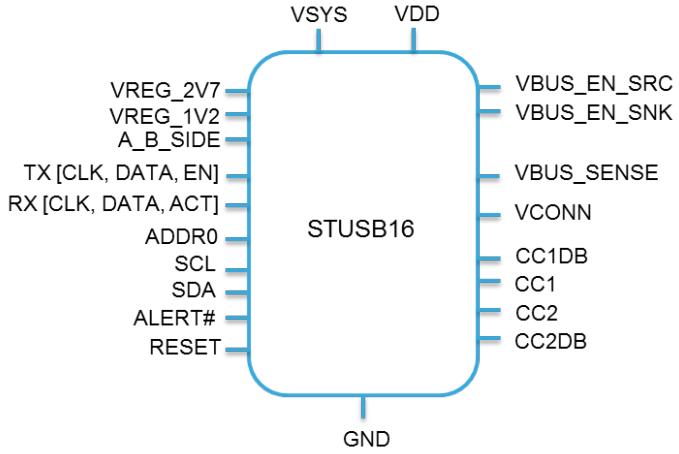
USB-PD Interface:

STUSB16xx



QFN-24 (4x4 mm)
Pin to pin compatible with STUSBxx family

2 x 1.6 mm² - 400um
2.5 x 2 mm² - 500um
CSP



Features

- Dual Role Type-C Interface with BMC
- Dual role capability
- Configurable start-up profiles
- 600mA VCONN
- 120uA Idle current measured
- Interface with external MCU through I²C+Interrupt
- Integrated Voltage monitoring
- Integrated V_{BUS} discharge path
- Accessory support
- Dual Power supply:
  - V_{SYS} = 3.3V,
  - V_{DD} [4.6V; 22V] (from V_{BUS})

Benefits

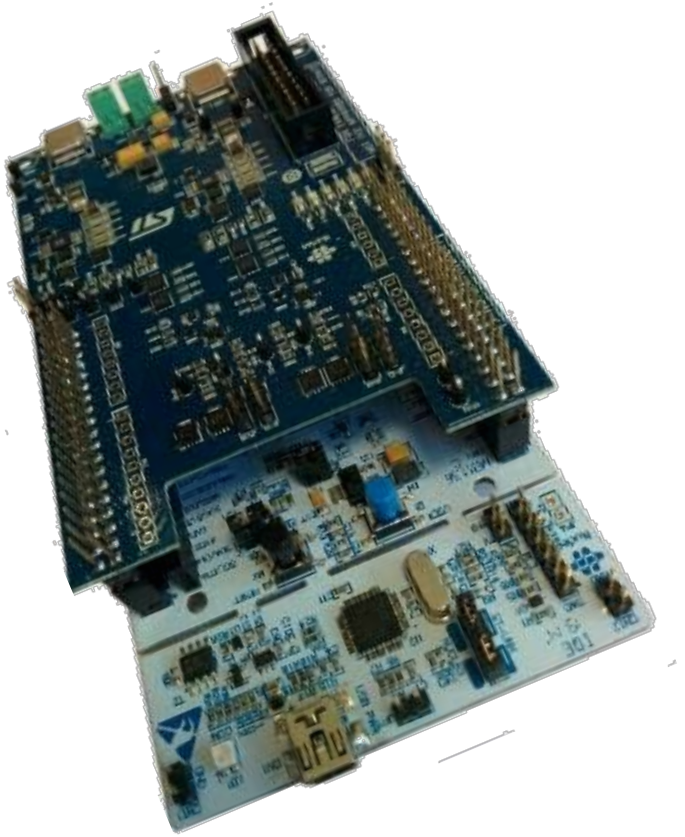
- Low Pin count
- Integrated BMC transceiver
- Simple, Robust
- Configurable, Flexible
- Optimized for Portable applications
- P2P with STUSB4x

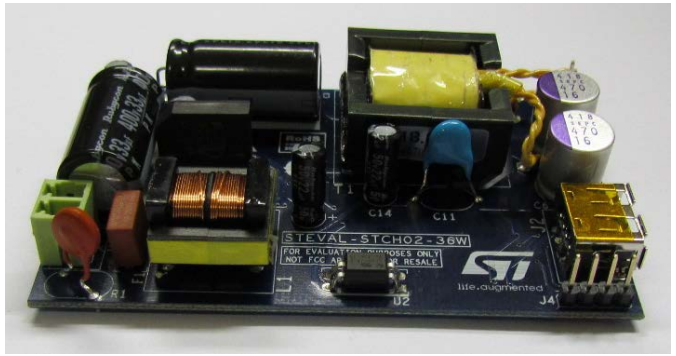
life.augmented

https://www.st.com/usb-type-c

USB-PD Type-C Solution

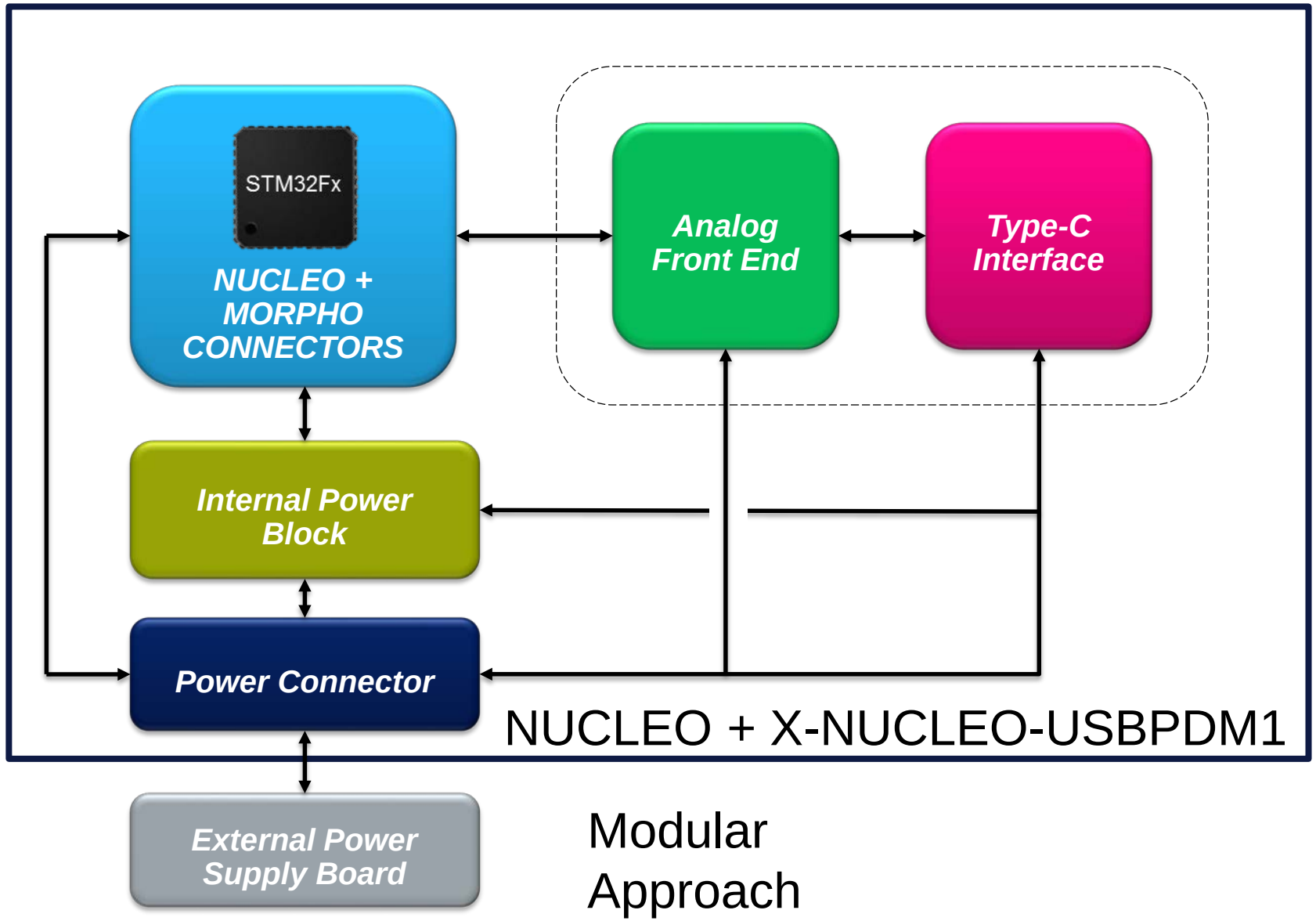
- AC/DC Multi-output 36W Converter
  - Based on STCH02 QR controller
  - Multiple Output voltages (5V, 9V, 12V)
- STM32 Embedded Software Solution
  - to interface with USB-C connector
  - to handle the USB Power Delivery protocol
  - cost effective and popular 32bit Microcontroller
- HW platform based on X-Nucleo Shield





life.augmented

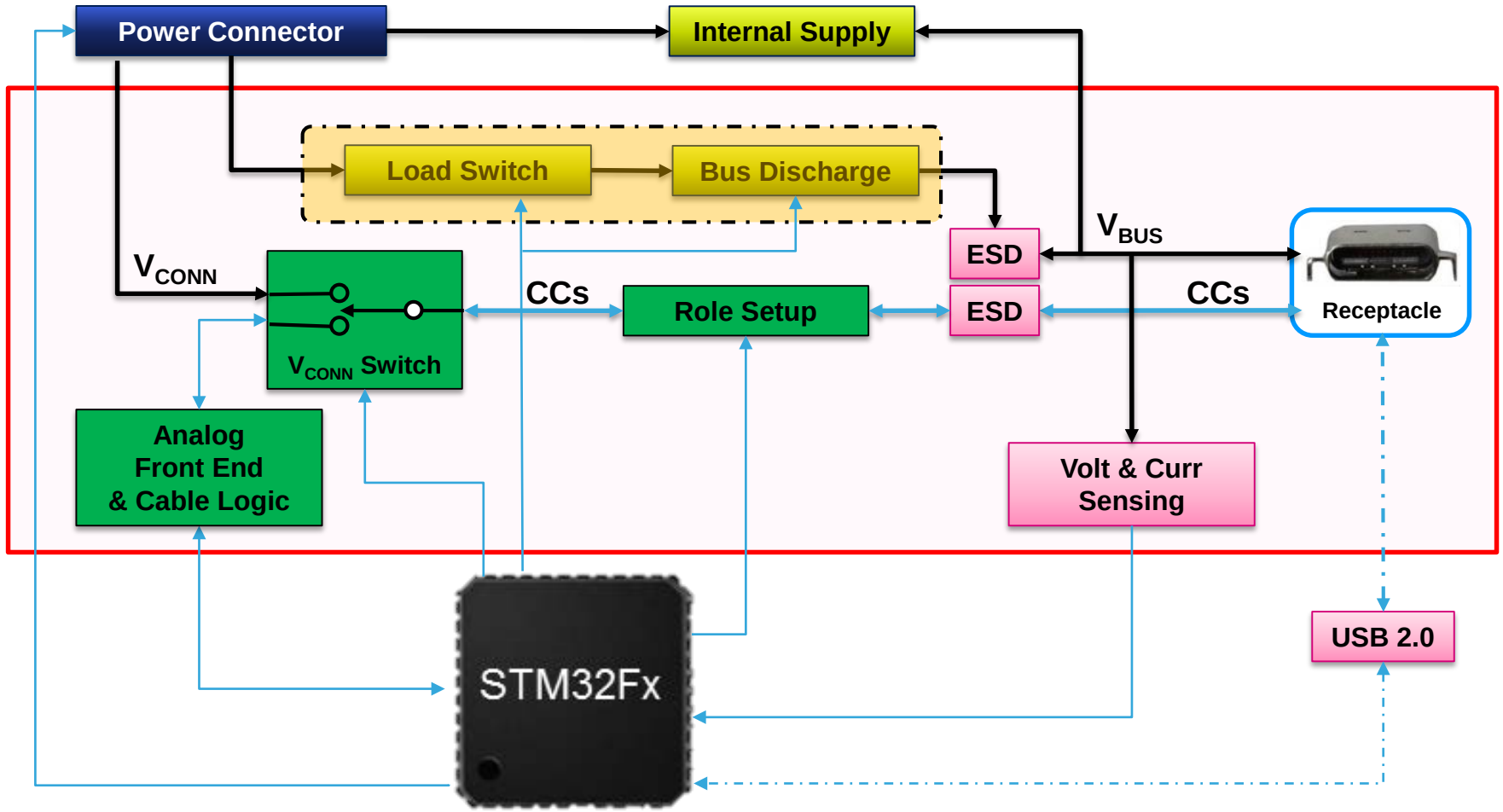
Block Diagram



Modular Approach

life.augmented

Block Diagram: Features



On board functionalities activable if not available on external power supply board.

USB 2.0 USB 2.0 hooked to Type-C on Port 0, if available on STM32.

life.augmented

AC/DC 36W 5/9/12V

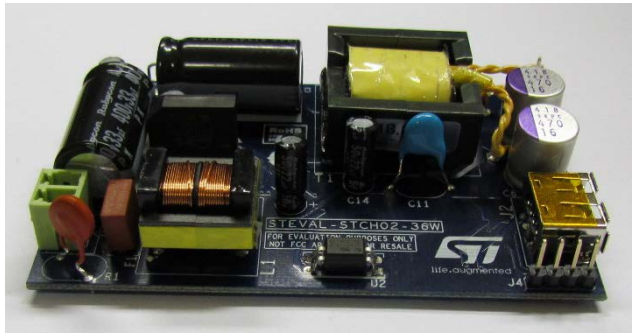
Efficiency and no Load Consumption

Efficiency @ 115Vac				
Load	**Iout [A]**	**5V**	**9V**	**12V**
100%	3.000	83.18%	85.17%	85.41%
75%	2.250	80.61%	85.34%	85.53%
50%	1.510	80.20%	84.71%	84.61%
25%	0.750	80.92%	85.17%	81.67%
Average		***81.23%***	***84.45%***	***84.30%***

Efficiency @ 230Vac				
Load	**Iout [A]**	**5V**	**9V**	**12V**
100%	3.000	82.42%	85.56%	86.35%
75%	2.250	81.44%	84.65%	85.47%
50%	1.510	80.65%	83.44%	84.08%
25%	0.750	77.89%	80.36%	80.05%
Average		***80.60%***	***83.50%***	***84%***

Input voltage	**Efficiency @ 10% Pout**		
	5V	**9V**	**12V**
$115V_{AC}$	***76.29%***	***76.68%***	***73.28%***
$230V_{AC}$	***73.09%***	***73.06%***	***70.54%***

Input voltage	**No load consumption** ***5V***
115Vac	**11mW**
230Vac	**12mW**



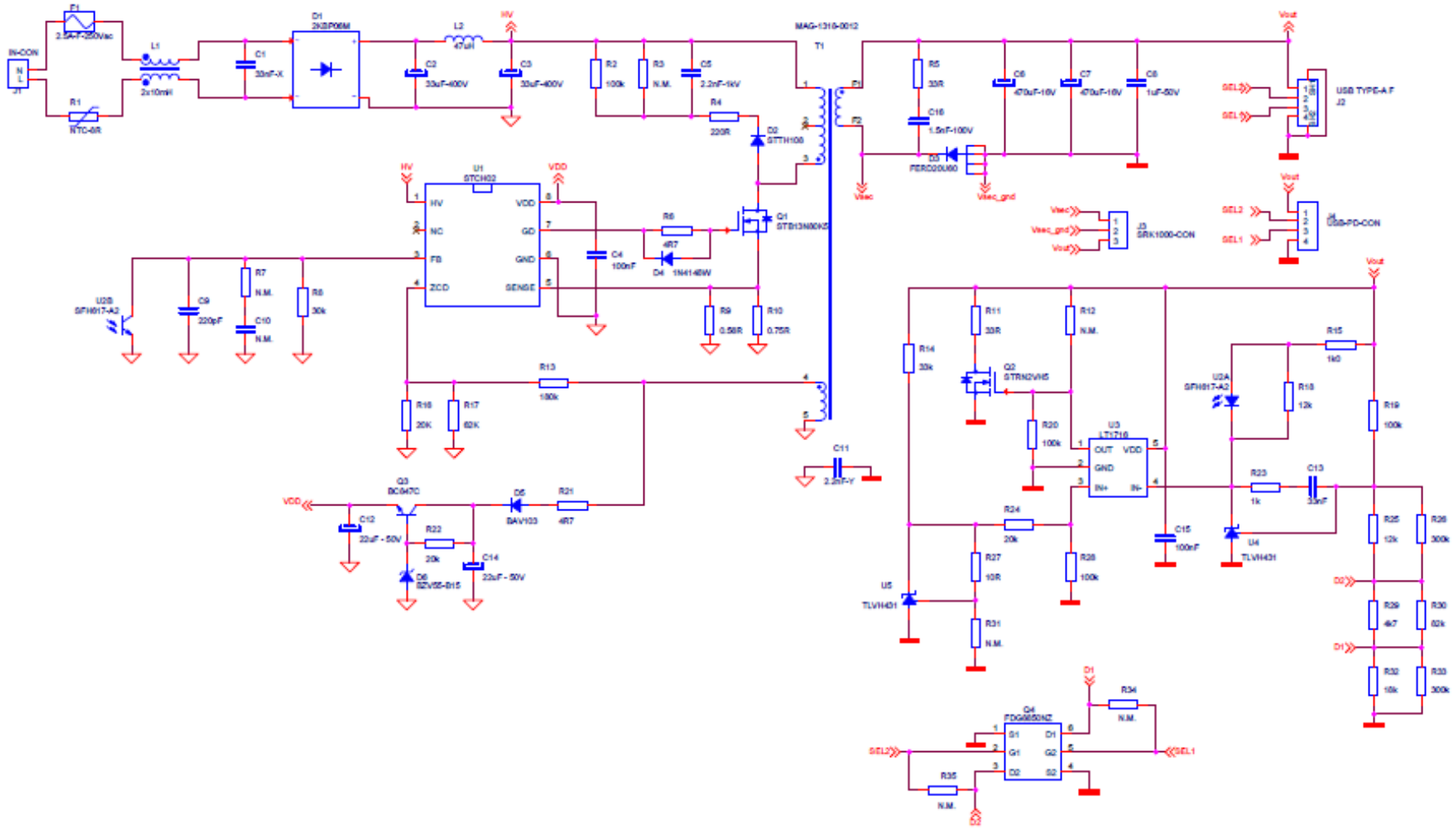
- **36W 5/9/12V board**

- Please note that the values of efficiency are penalized by the power losses on secondary rectifier diode.
- The efficiency can be **improved around 4%** using synchronous rectification

life.augmented

AC/DC 36W 5/9/12V

Schematic



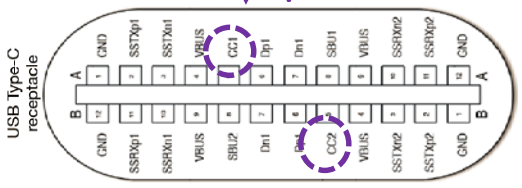
life.augmented

MCU + Discrete AFE Overview

GPI/Os

Discrete Analog FE

CC1/CC2



USB Type-C connector

- STM32 Embedded Software Solution to interface with USB-C connector and to handle the USB Power Delivery protocol.
  - *Hardware : Entry level Cortex-M0 based STM32F0 microcontroller series with simple discrete Analog Front End PHY*
  - *Embedded Software : USB-C & PD Middleware*

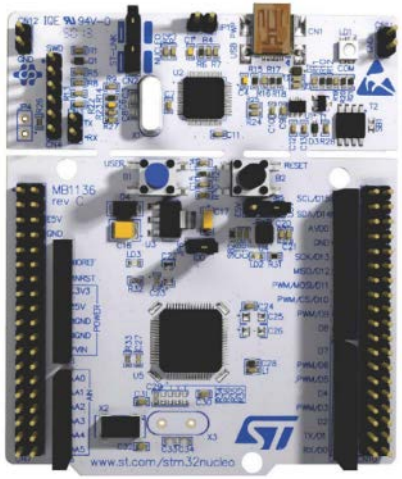
Best device for 2 ports management : STM32F051 in 48 pin package
Best device for 1 port management : STM32F051/31 in 20/32 pin package

life.augmented

X-NUCLEO-USBPDM1

- USB-C Power Delivery expansion board with two USB Type-C connectors for two port management.

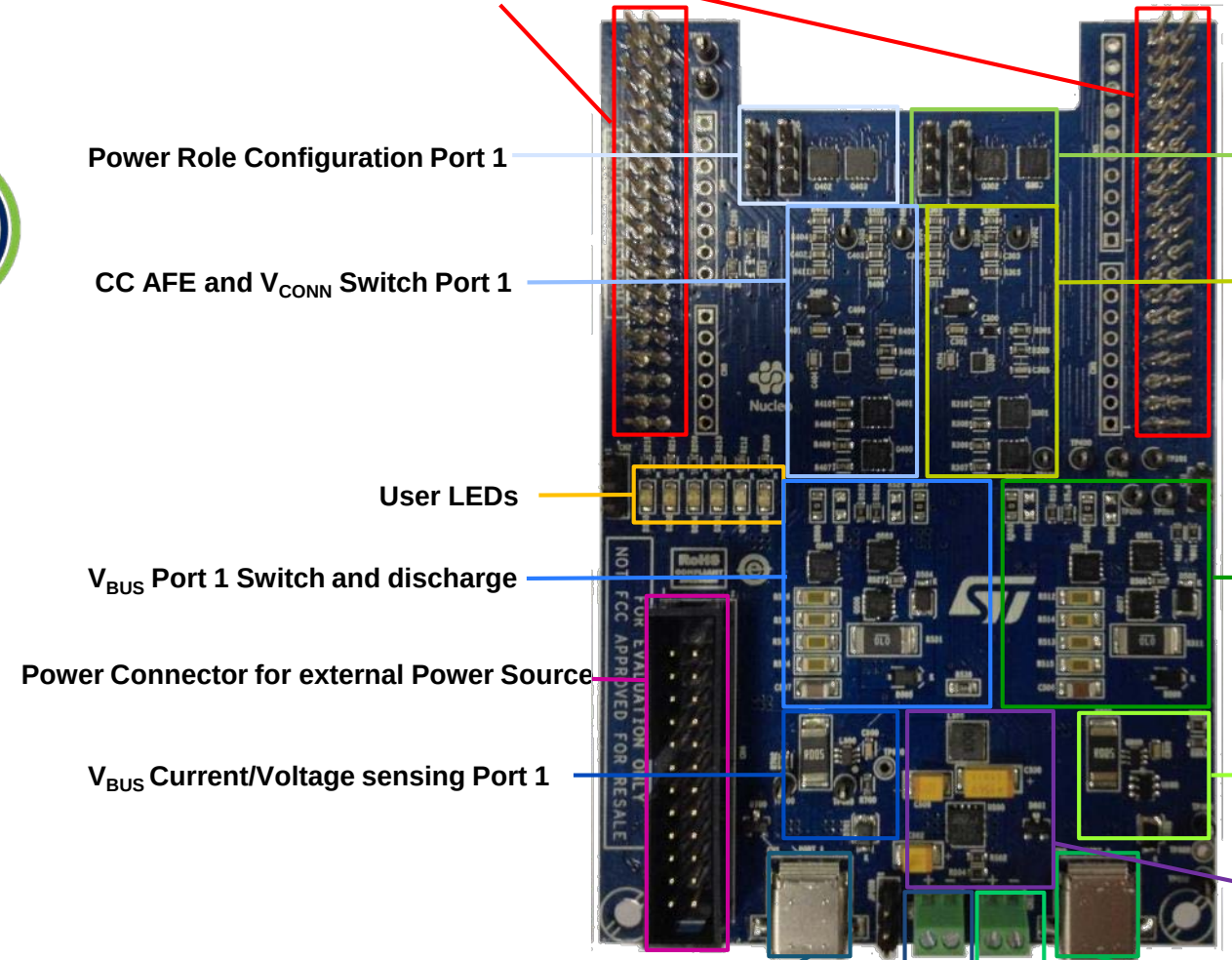
- Main features:
  - Two Dual Role Ports
  - Dedicated Power Connector to interface with external Power Supply board providing different profiles (up to 20V and 5A) and V_{CONN}
  - On-board Power management able to provide internal needed voltages from V_{BUS}
  - Six debug LEDs
  - USB 2.0 interface capability available on one port
  - Compatible with STM32 Nucleo boards
  - Equipped with ST morpho connectors



life.augmented

X-NUCLEO-USBPDM1

Board Details



life.augmented