Digital Power Conversion with STM32G4

STM32G4 sync buck converter demo

Biricha Digital design tools for STM32

STM32Cube firmware for Vienna Rectifier

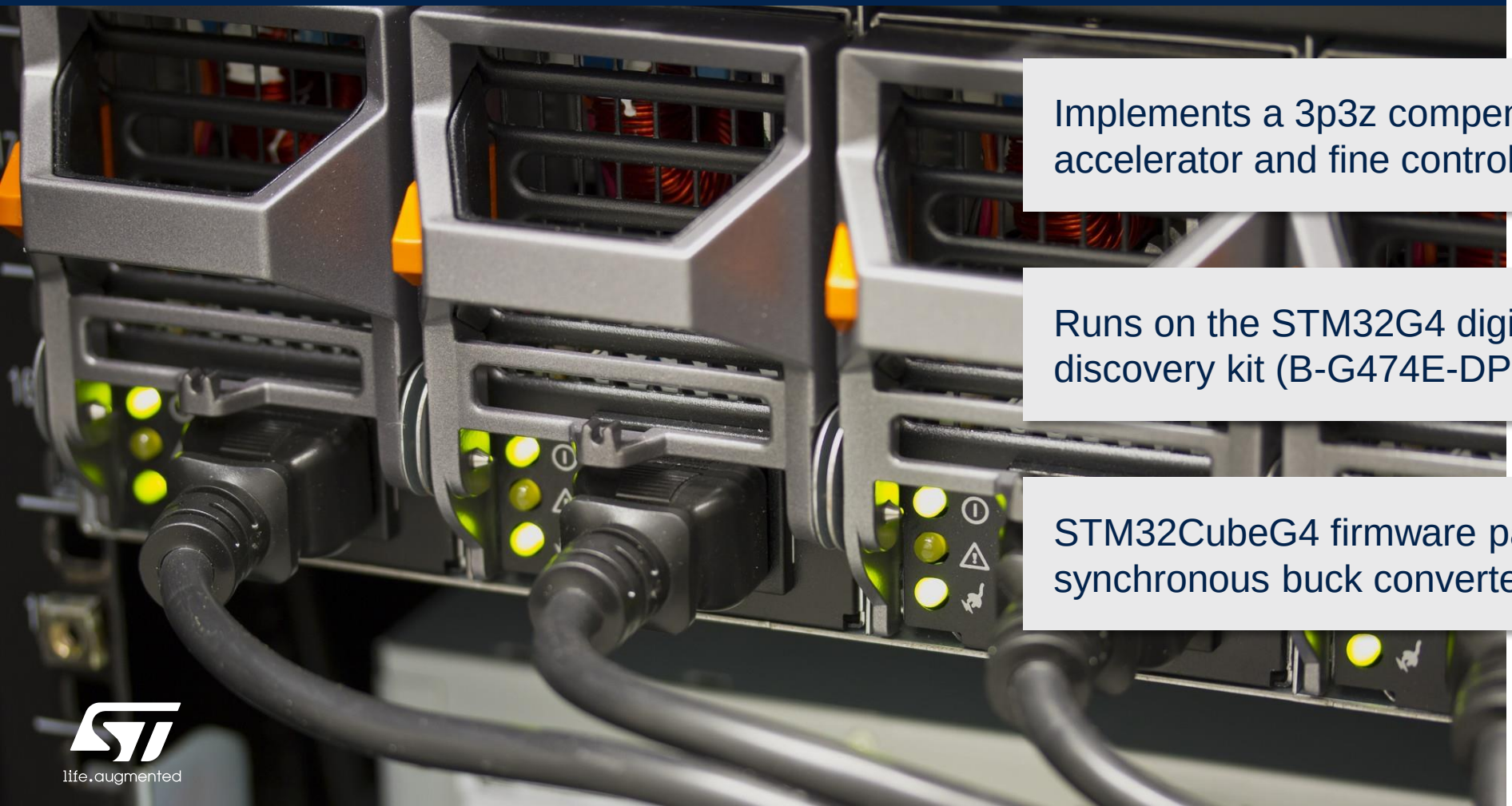
STM32G4 mixed signal MCU

life.augmented

Digitally controlled synchronous buck converter

STM32**G4**

STM32G4 synchronous buck converter demonstration



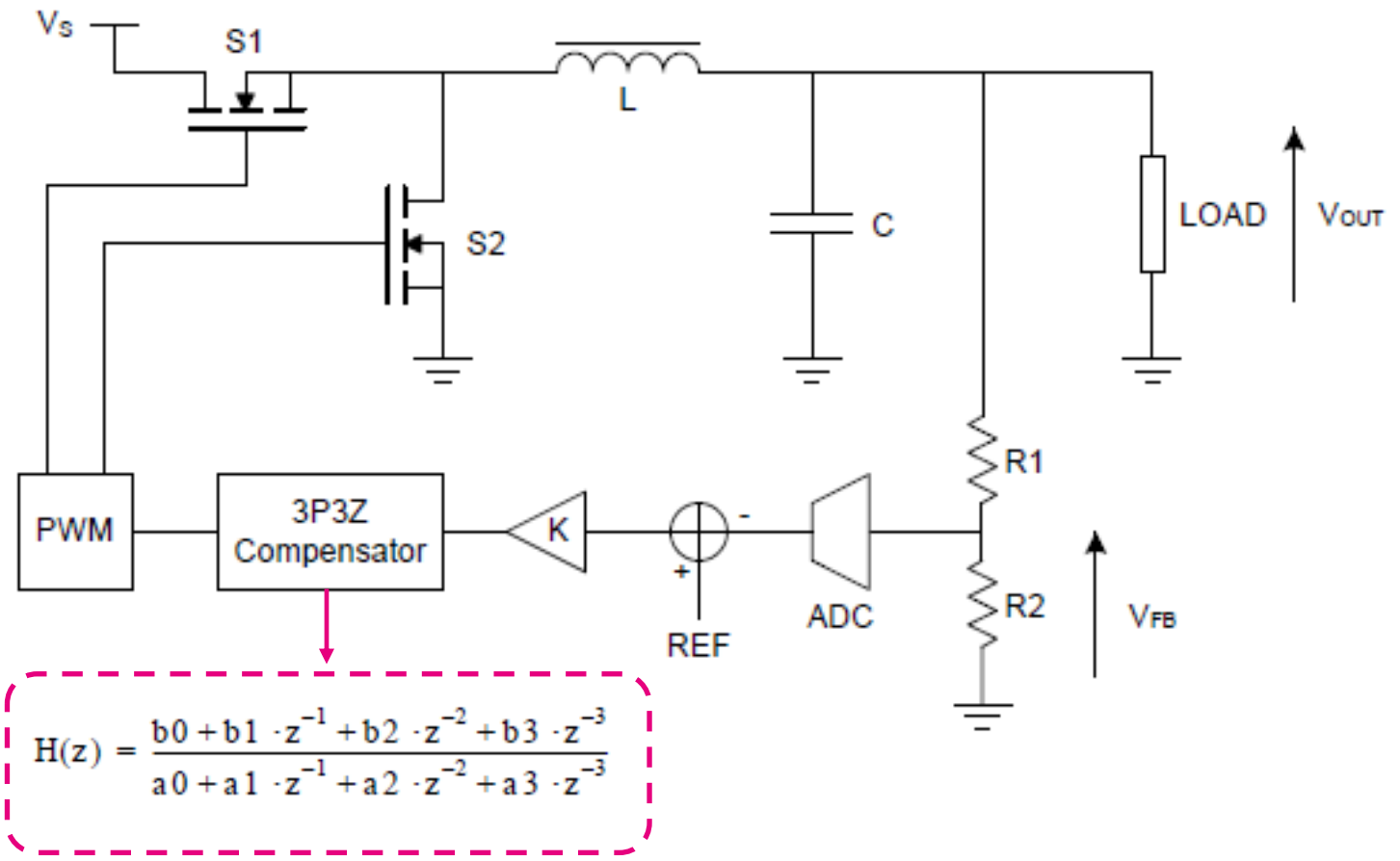
- Implements a 3p3z compensator using the FMAC accelerator and fine control with the HRTIM (184ps)
- Runs on the STM32G4 digital power supply discovery kit (B-G474E-DPOW1)
- STM32CubeG4 firmware package includes the synchronous buck converter example

life.augmented

Synchronous buck converter demonstration

Demo specifications:

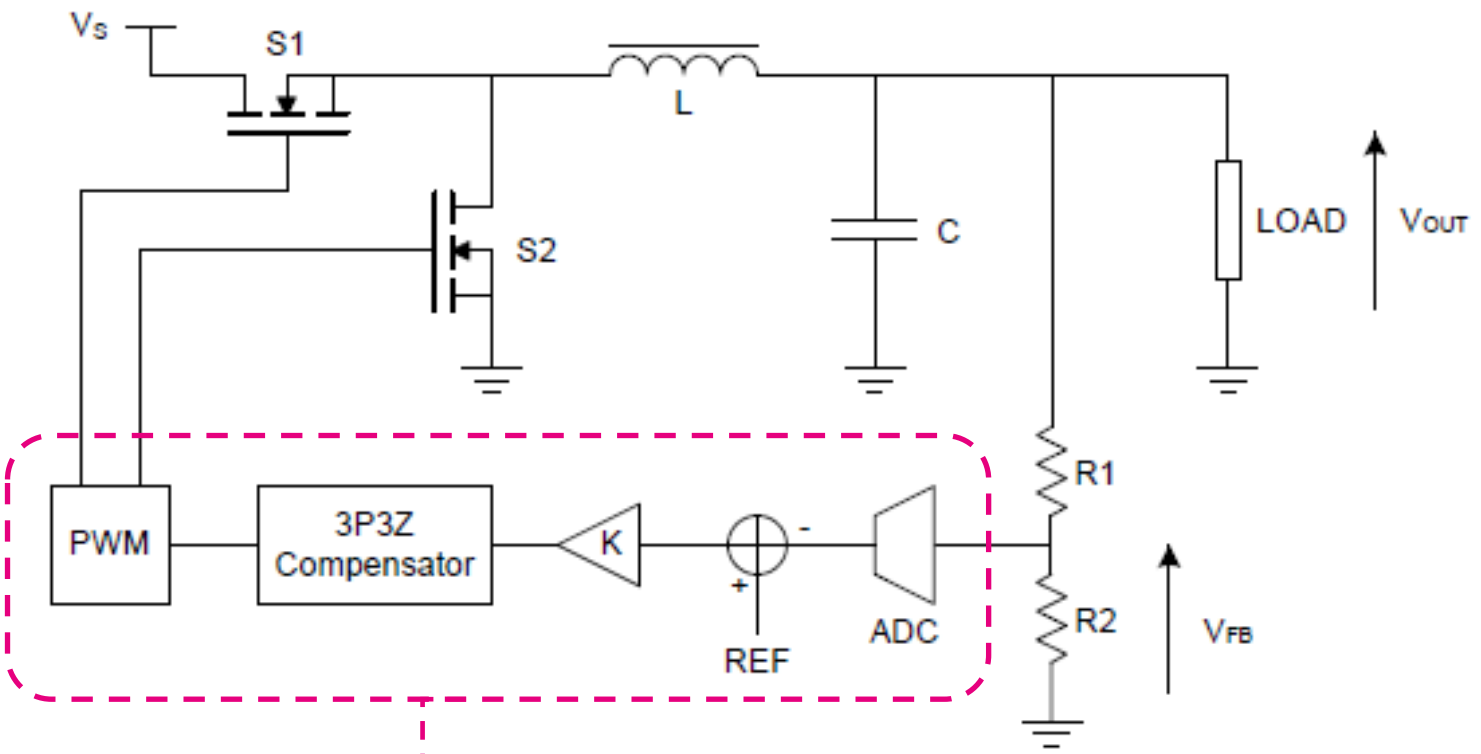
- Input supply voltage: 5 V
- Output voltage: 3.3 V
- Maximum current: 0.5 A
- Target ripple: 0.5% (16.5 mV)
- Overshoot (50% load step): 5 mV
- Control mode: Voltage, digital
- Switching frequency: 200 kHz
- Sampling frequency: 200 kHz
- Crossover frequency: 8 kHz
- Phase margin at crossover: 50 degrees
- Duty cycle limit: 90%



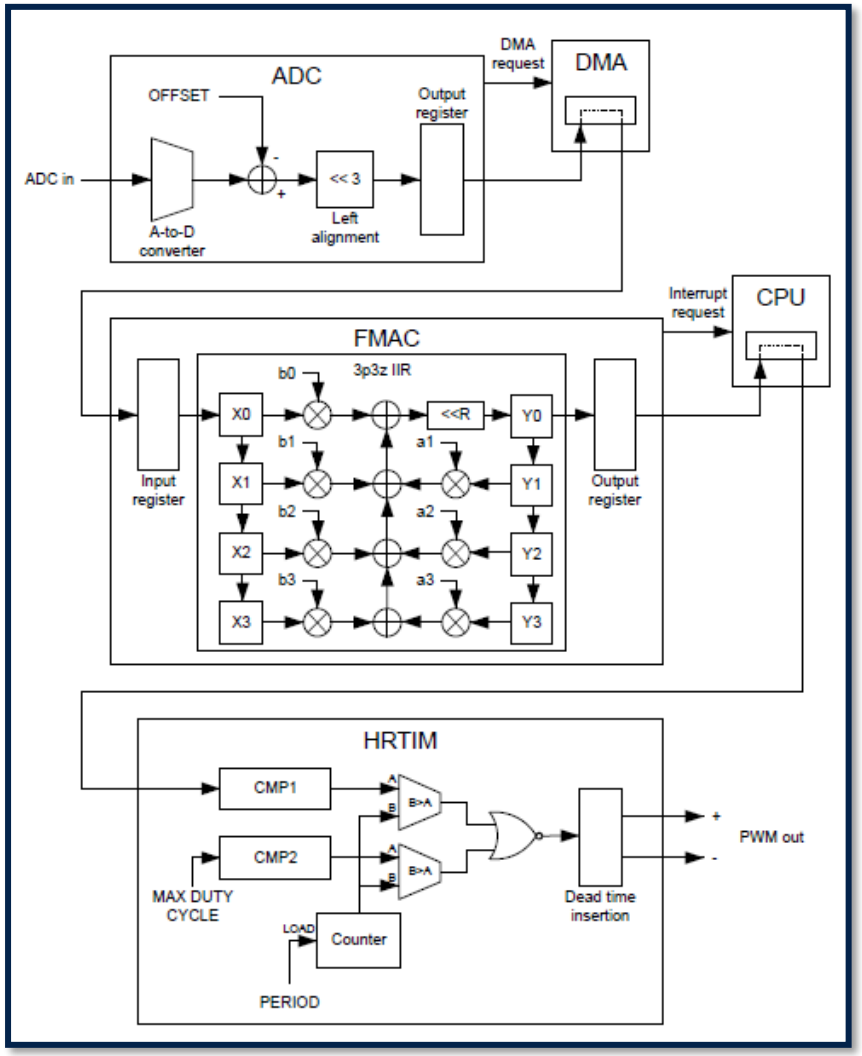
life.augmented

STM32G4

STM32G4 implementation

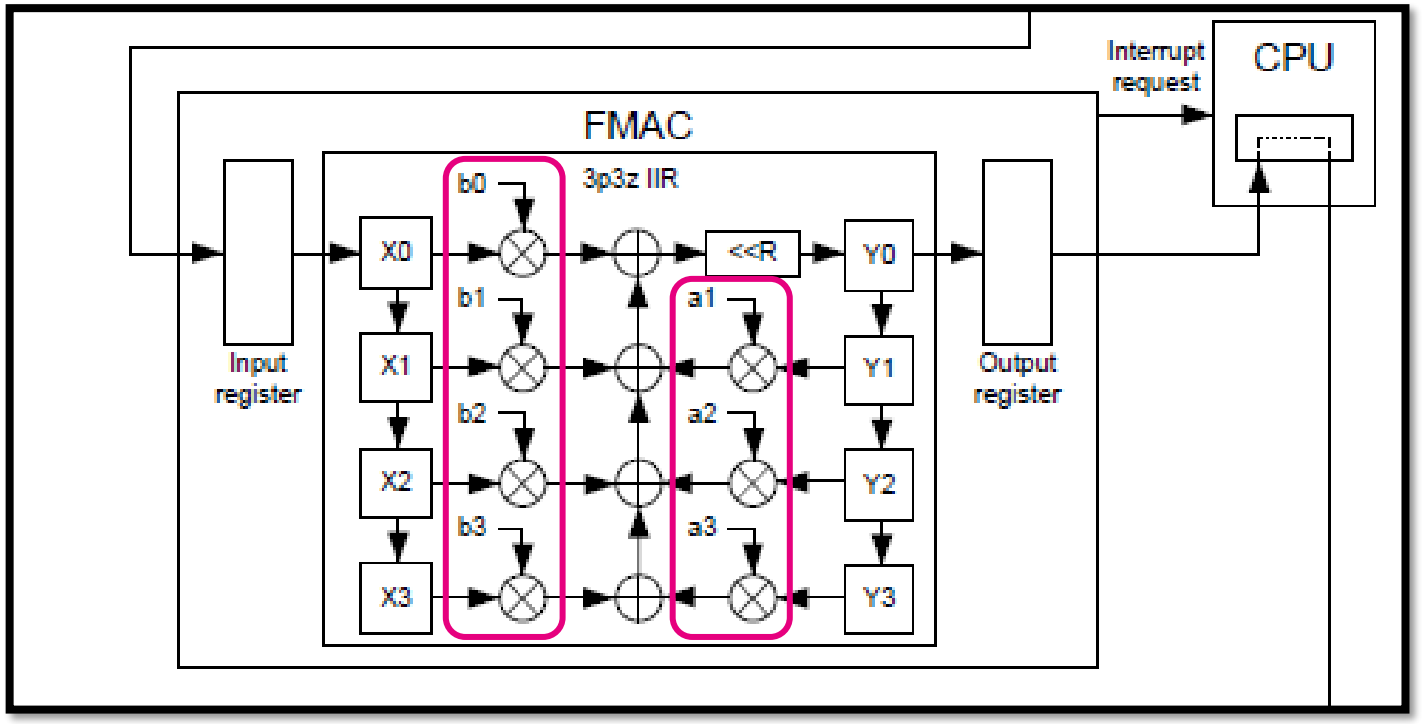


STM32G4 implementation



life.augmented

3p3z compensator coefficients



BIRICHA DIGITAL

Generated using the ST WDS tool from Biricha Digital

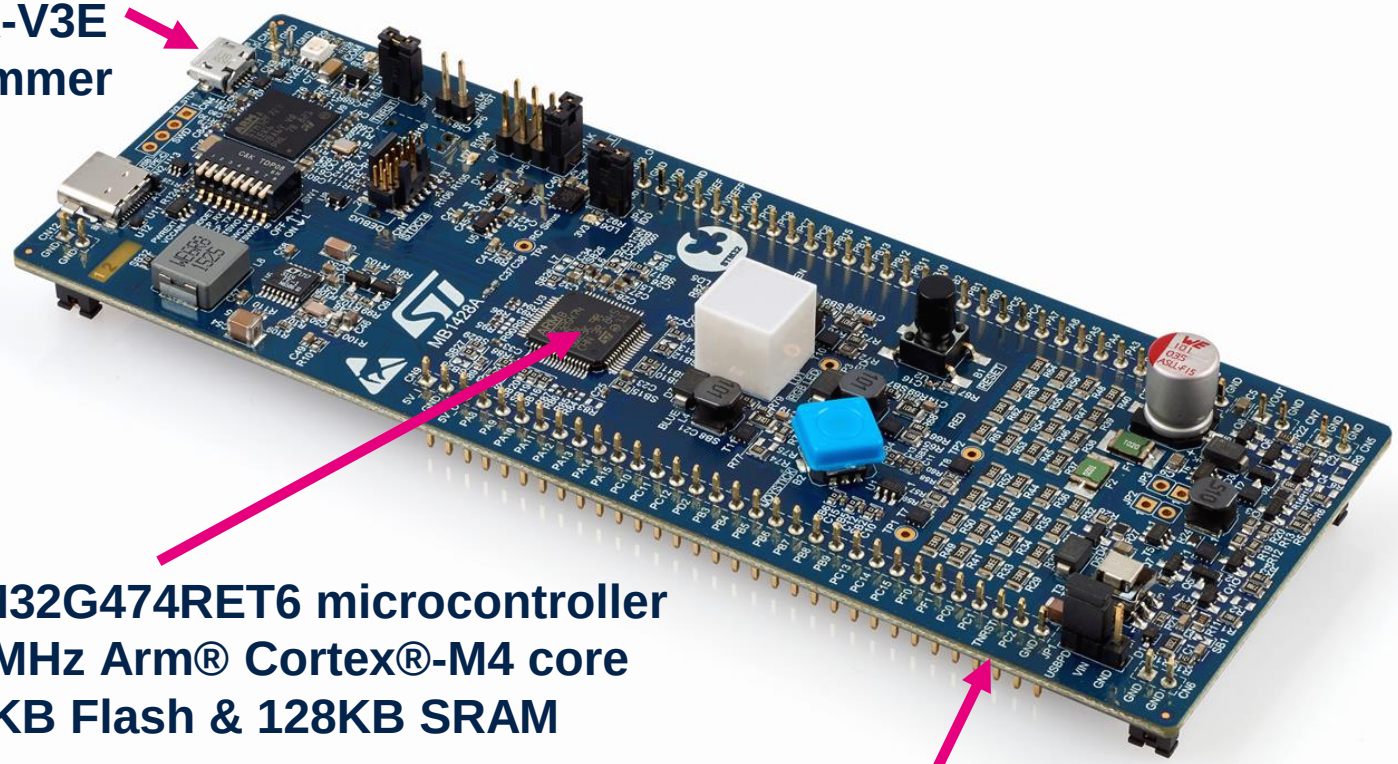
A1	1.521558814252	B0	1.553498447795
A2	-0.356458881462	B1	-1.361492224301
A3	-0.16509993279	B2	-1.547612874966
K	115.36533642	B3	1.36737779713

Copy to Clipboard

life.augmented

Digital power discovery kit (B-G474E-DPOW1)

On-board STLINK-V3E debugger/programmer



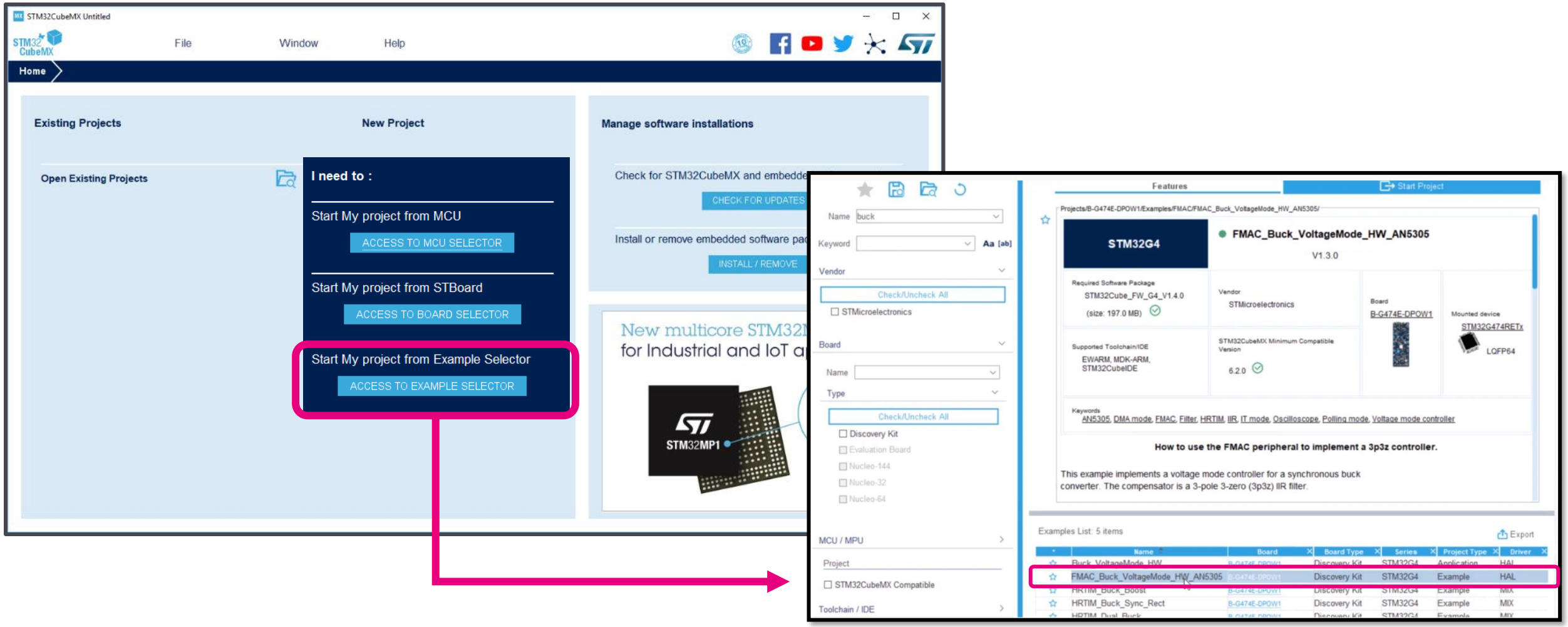
STM32**G4**

STM32G474RET6 microcontroller
170MHz Arm® Cortex®-M4 core
512KB Flash & 128KB SRAM

Sync Buck converter circuit with onboard resistor loads

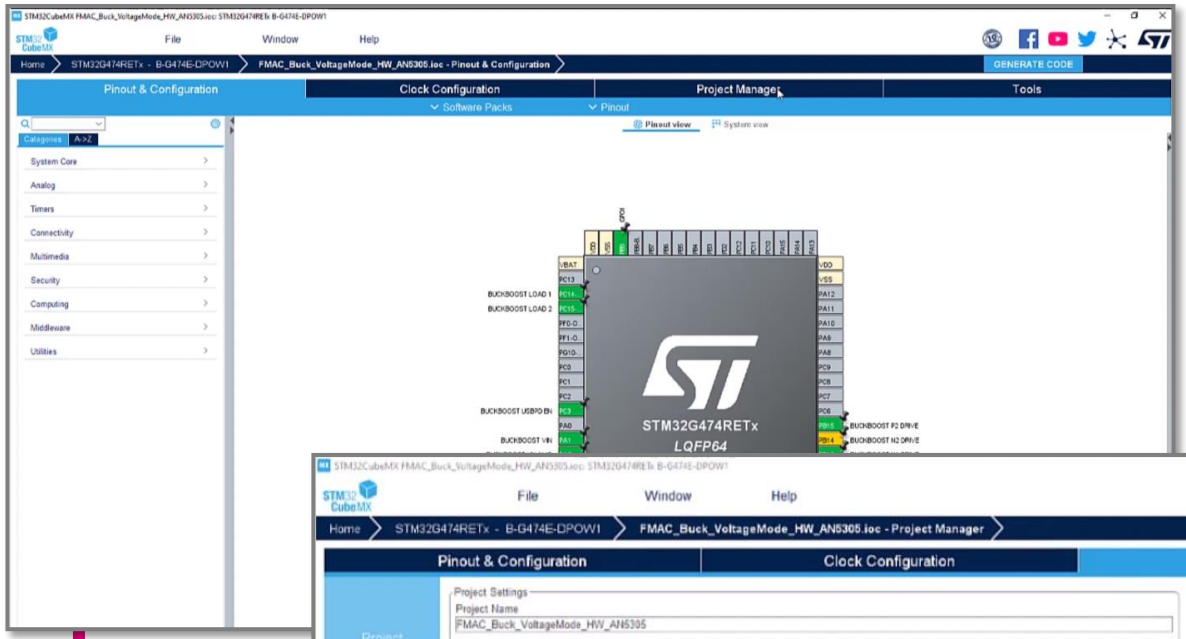
life.augmented

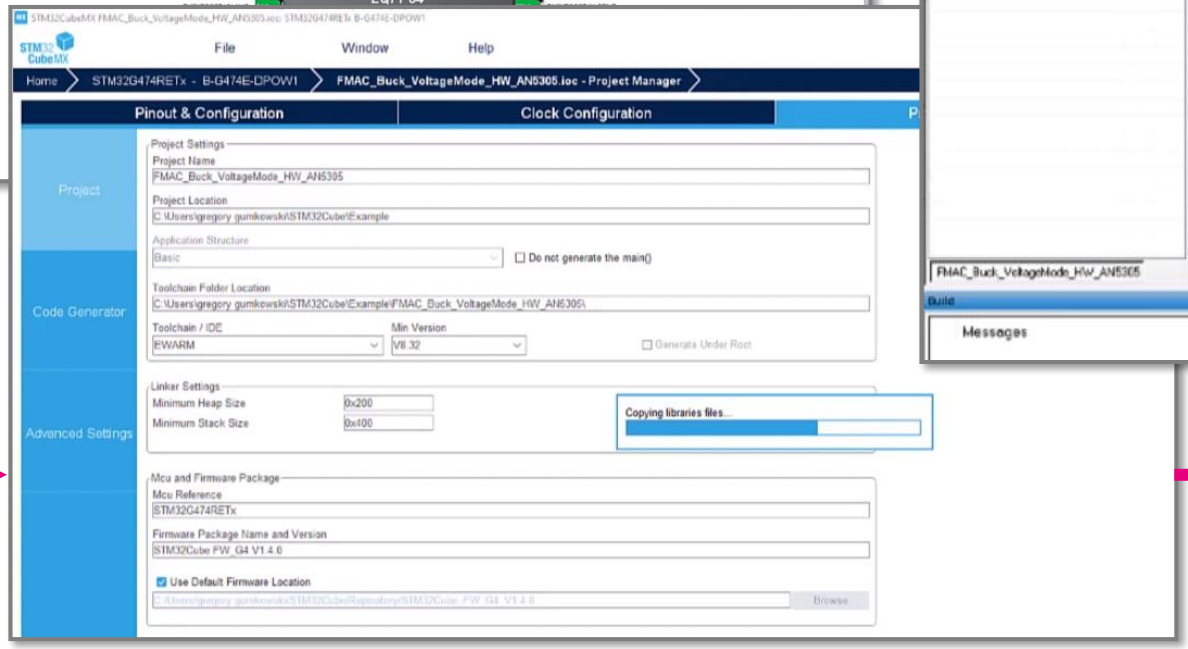
STM32CubeMX example selector

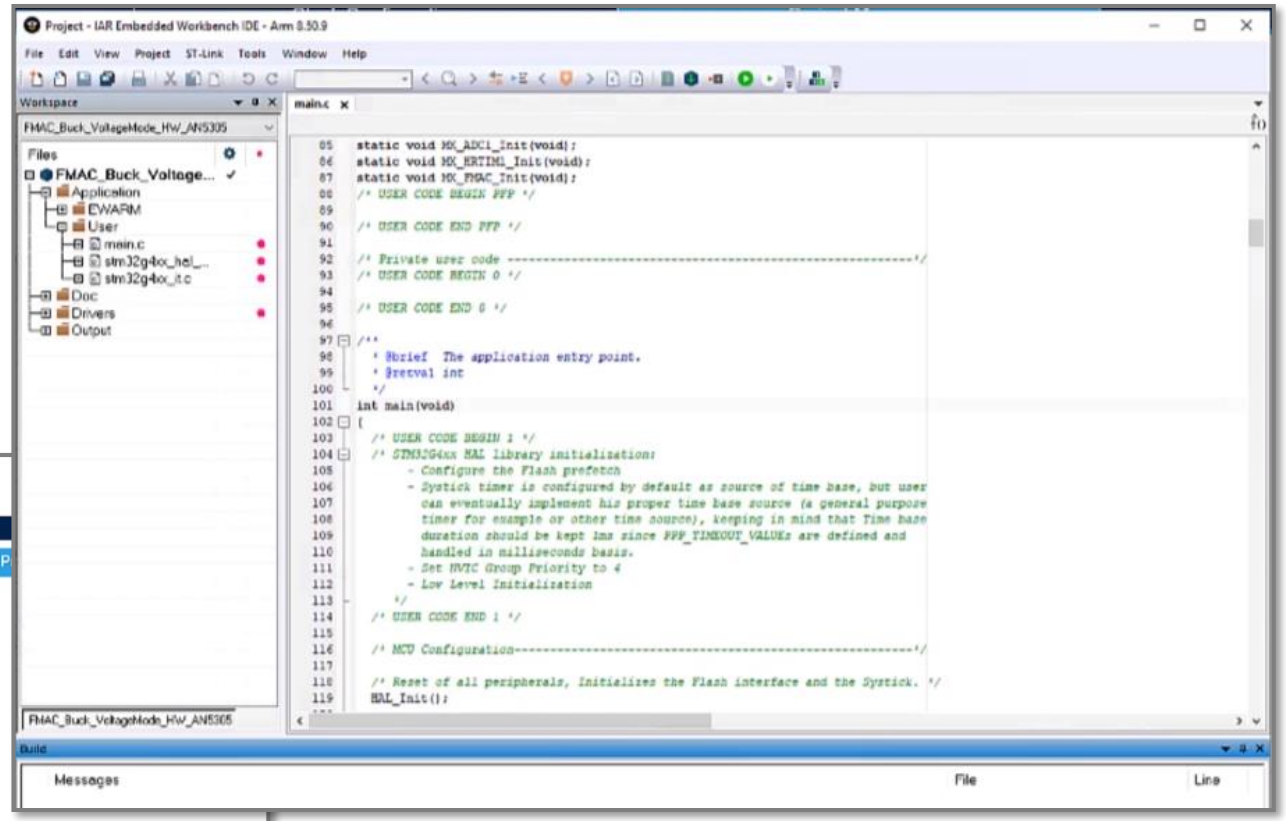


life.augmented

STM32CubeMX code generation, compile and program from IDE







generate

compile & program

life.augmented

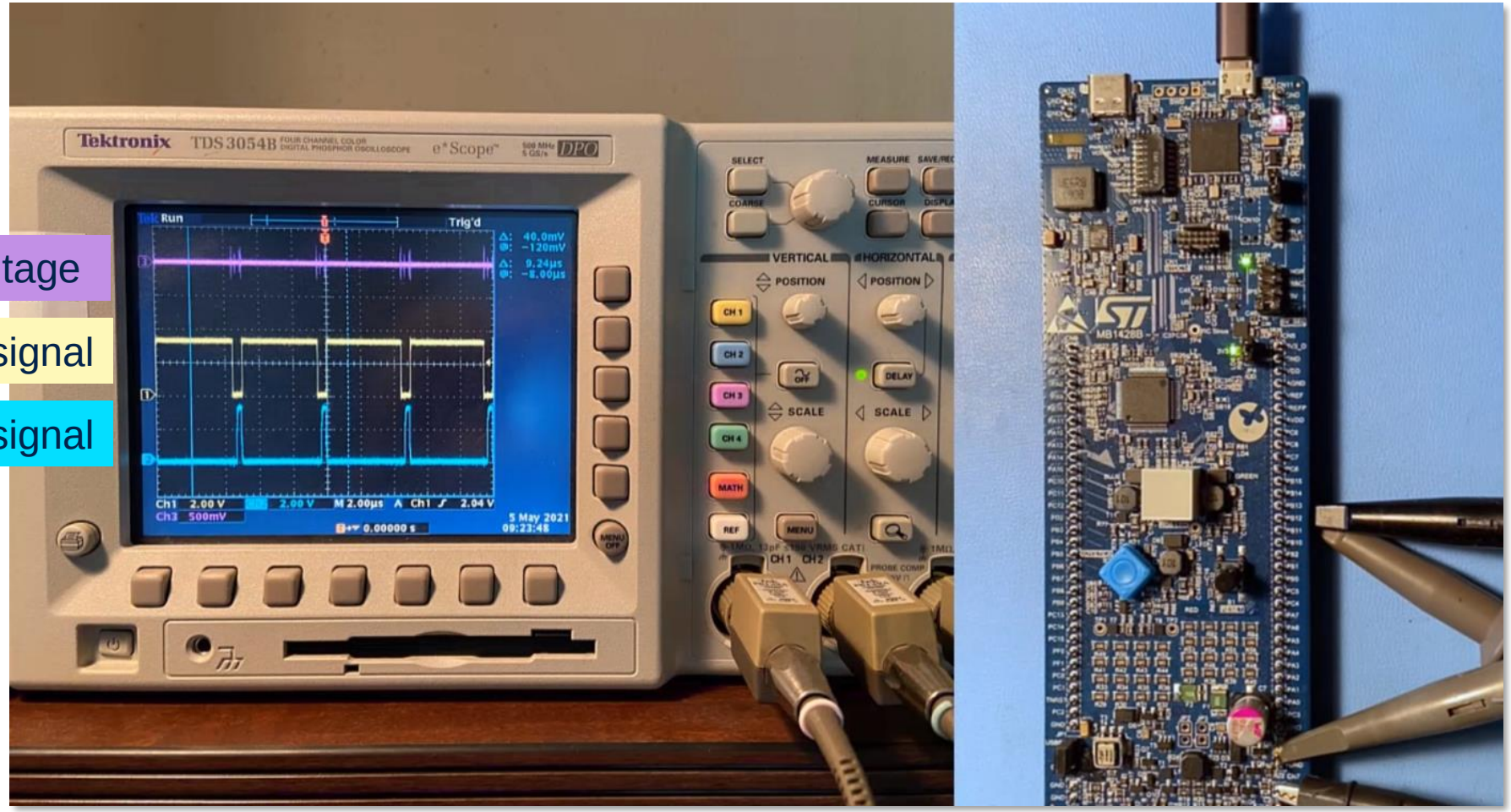
STM32G4

Run application, Measure performance

Output voltage

S1 PWM signal

S2 PWM signal



life.augmented

Synchronous buck converter example AN5303 measurements

200Khz switching frequency, 5uS period
ADC triggered on high-side rising edge

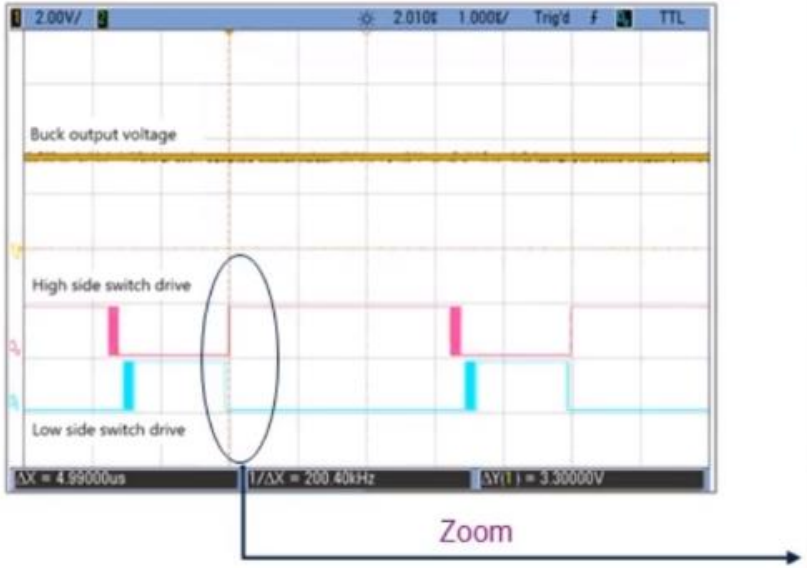
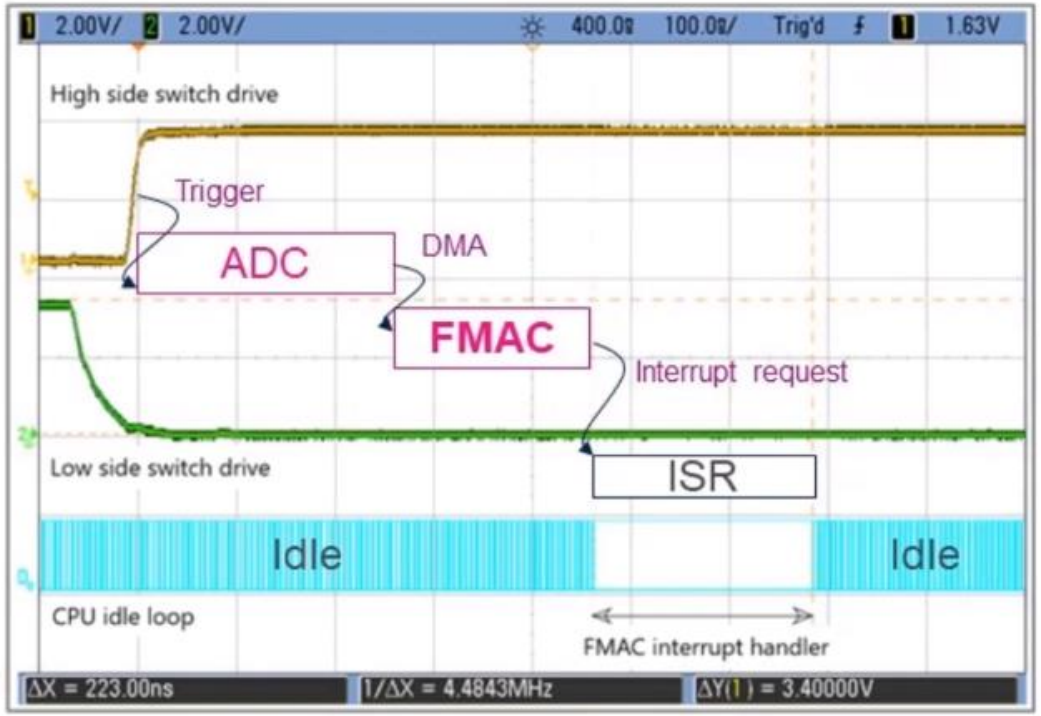


Figure 21. **CPU load**



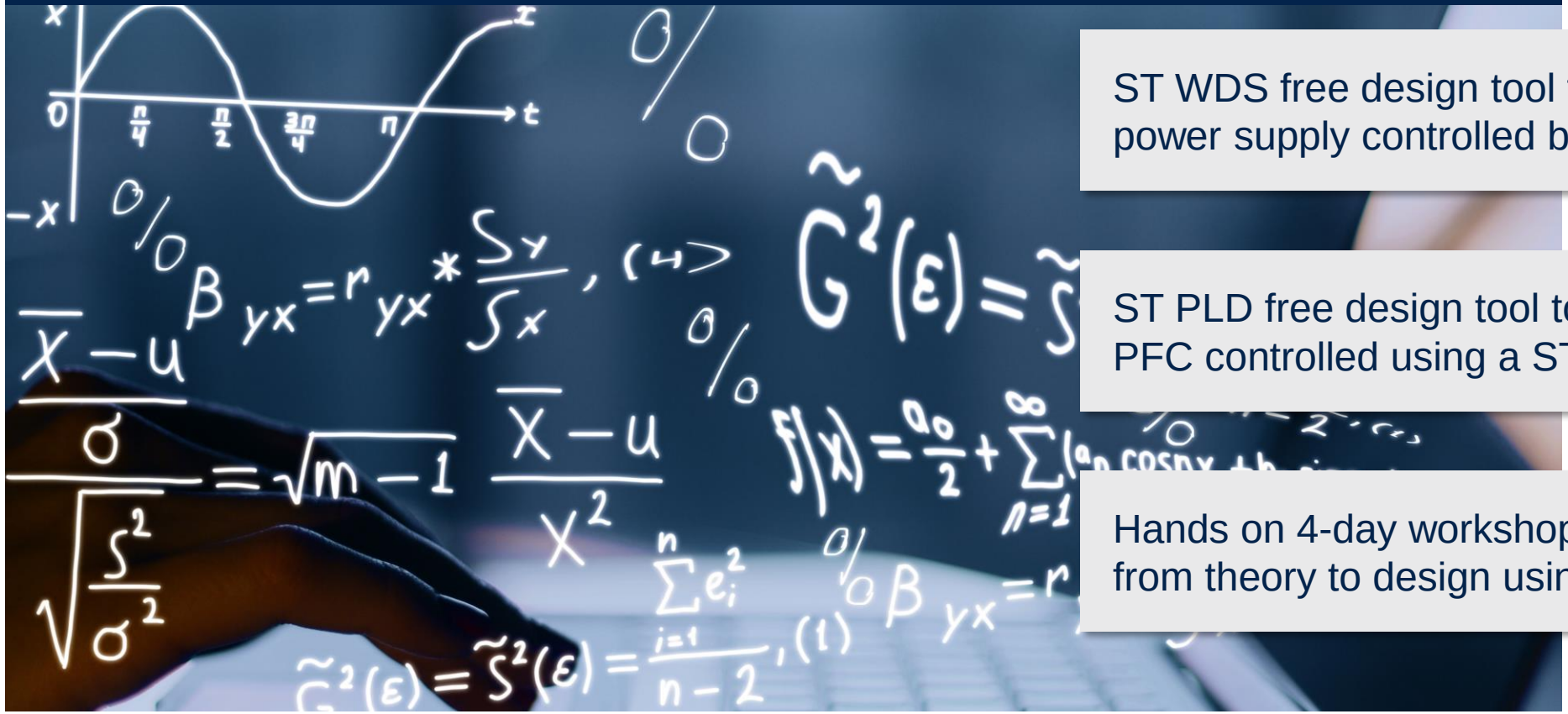
Hardware
ADC & FMAC
460ns

Software (CPU)
223ns

Less than 5% CPU bandwidth at 200kHz switching frequency

Design tools and workshops using the STM32G4

Biricha Digital design tools for STM32



ST WDS free design tool to quickly stabilize a digital power supply controlled by a STM32

ST PLD free design tool to quickly stabilize a digital PFC controlled using a STM32

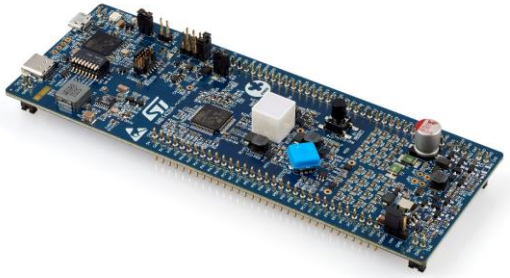
Hands on 4-day workshops take you step by step from theory to design using the STM32G4

Biricha design tools for STM32

BIRICHA DIGITAL

ST WDS free digital power supply design tool available from Biricha Digital for all STM32 MCUs

ST PLD free digital power faction correction design tool from Biricha Digital available for all STM32 MCUs



Examples provided for use with the STM32G474 Digital Power Discovery kit (B-G474E-DPOW1)

STM32**G4**

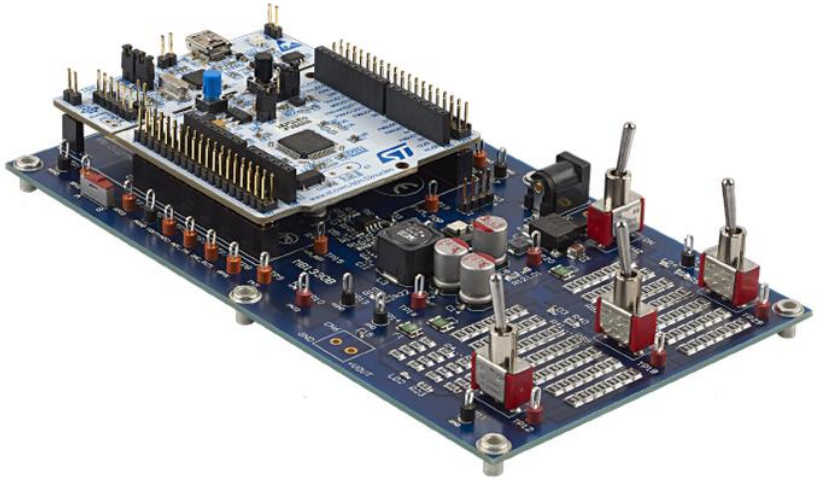
life.augmented

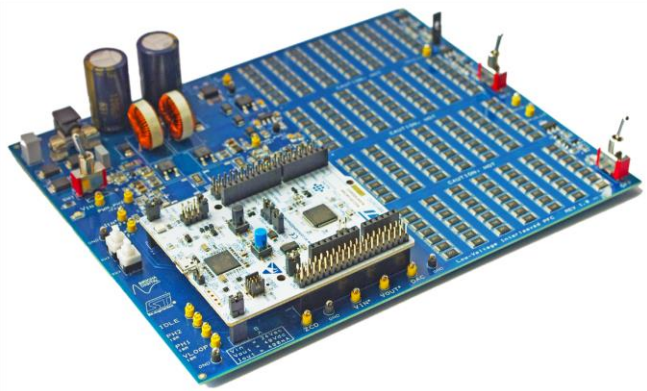
Biricha Digital 4-day hands on workshops

Upcoming Workshops

Digital Power Supply and PFC Design Workshop with STM32
May 10th 2022
Schaumburg, IL
USA

STM32 PSU/PFC design workshop
Step-in Digital Power technology





Agenda:
Day 1: Introduction to Digital Power Programming
Day 2: Digital Power Supply Design
Day 3: Peak Current Mode Control and Running Multiple Control Loops
Day 4: Digital PFC Design & Implementation

register at biricha.com

life.augmented

life.augmented | BIRICHA DIGITAL

Digital power conversion firmware solution

STM32Cube Firmware for Vienna Rectifier

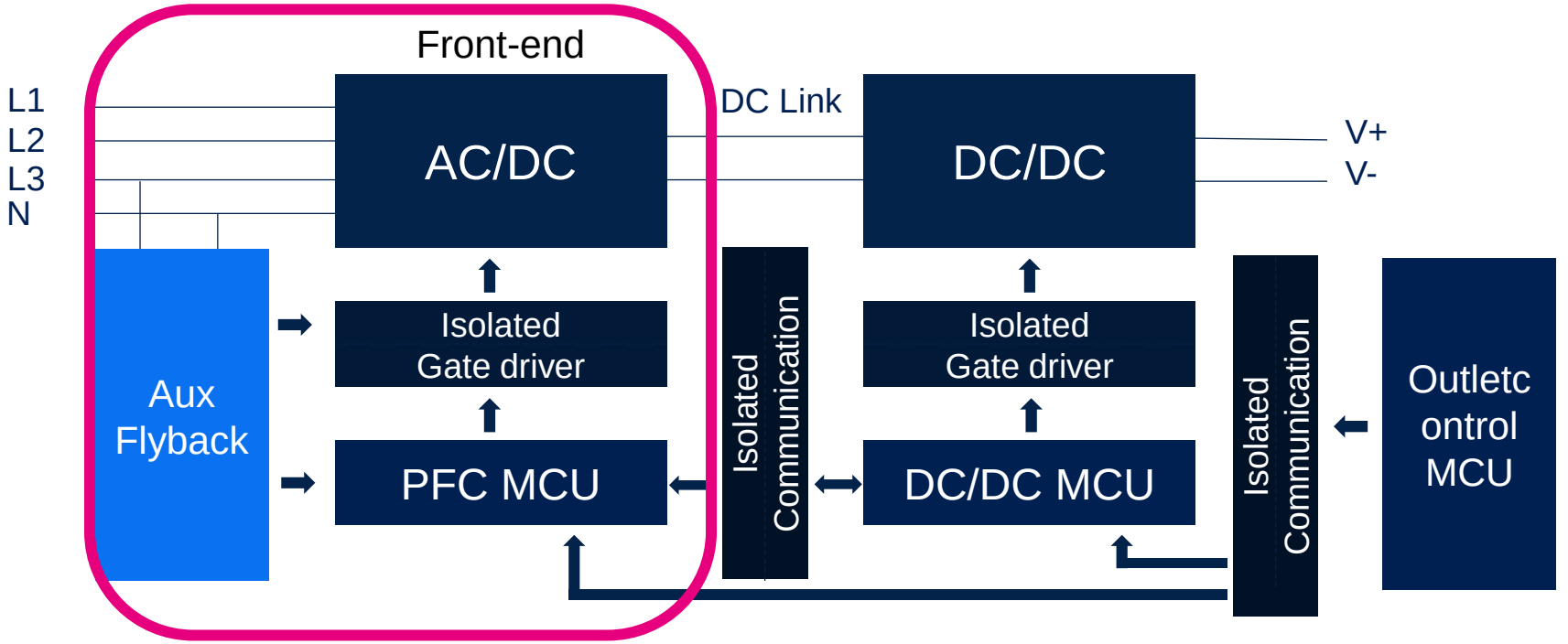
New design approach uses the eDesignSuite and STM32Cube ecosystem

STM32CubeMX and new STM32 digital power conversion function pack can generate code for a Vienna Rectifier converter

Generated code runs on the STM32G474 mixed signal MCU for a fully digital controlled solution

life.augmented

Front-end power converter



life.augmented

Vienna Rectifier solution description

The STDES-VRECTFD reference design is a complete solution for high-power three phase AC/DC rectifier applications based on the Vienna topology.

It features full digital control through the STM32G474RET3 MCU and provides both digital output voltage regulation and continuous conduction mode (CCM) current regulation for the maximum power quality related to total harmonic distortion (THD) and power factor (PF).

The high switching frequency of the SCTW35N65G2V SiC MOSFETs (70 kHz) and the multilevel structure allow a nearly 99% efficiency as well as the optimization of passive power components in terms of size and cost.

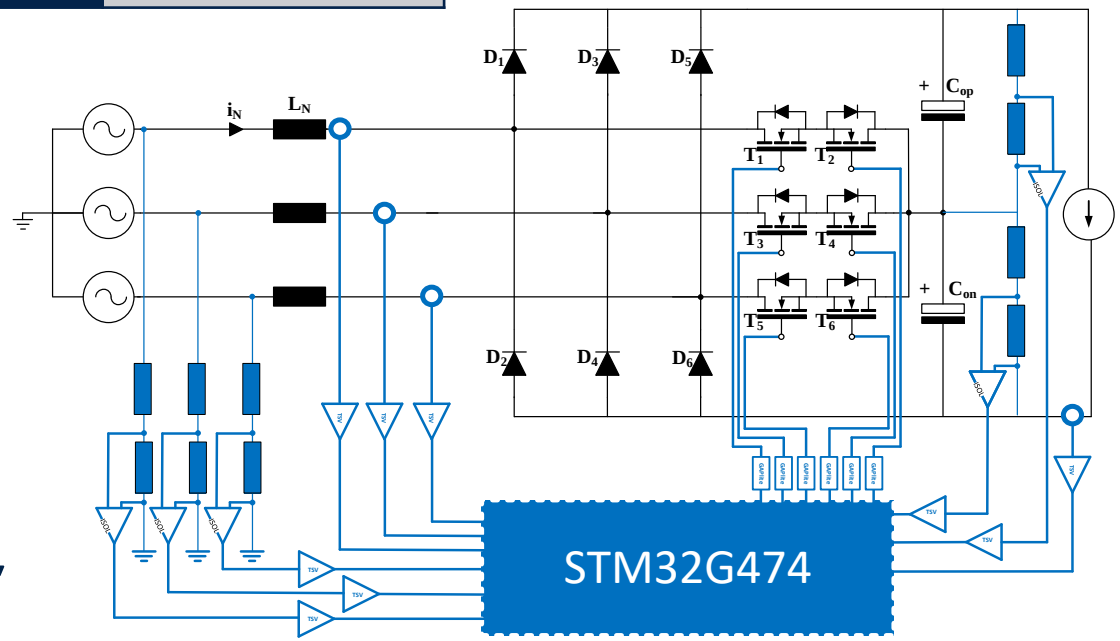
This high efficiency Vienna rectifier is designed for several end applications, such as electric vehicle (EV) and industrial battery chargers, and industrial equipment that requires a very high PF and a low THD.

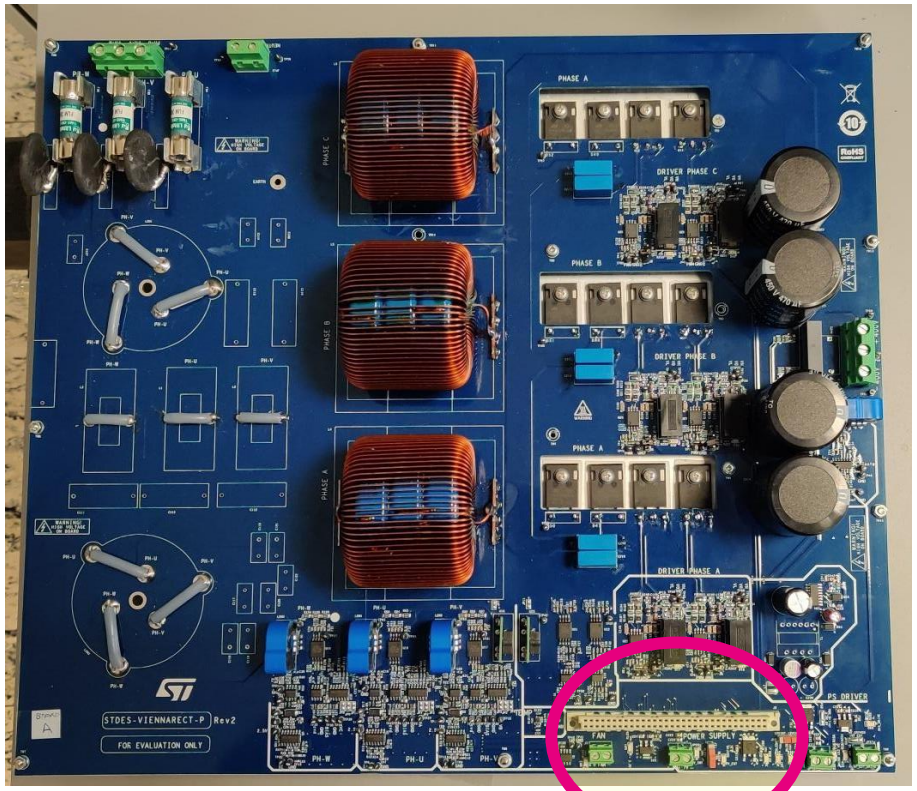
The STDES-VRECTFD is a fully assembled kit developed for performance evaluation only, not available for sale.

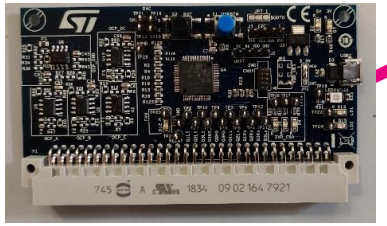
Vienna Rectifier solution (STDES-VRECTFD)

Main specifications

V_{AC}	400 Vac
V_{DC}	800 Vdc
P_{0ut_max}	15 kW
F_s	70 kHz
I_{ripple}	2.5A
V_{out_ripple}	10 Vpp
PF	> 0.9
THD	< 5%



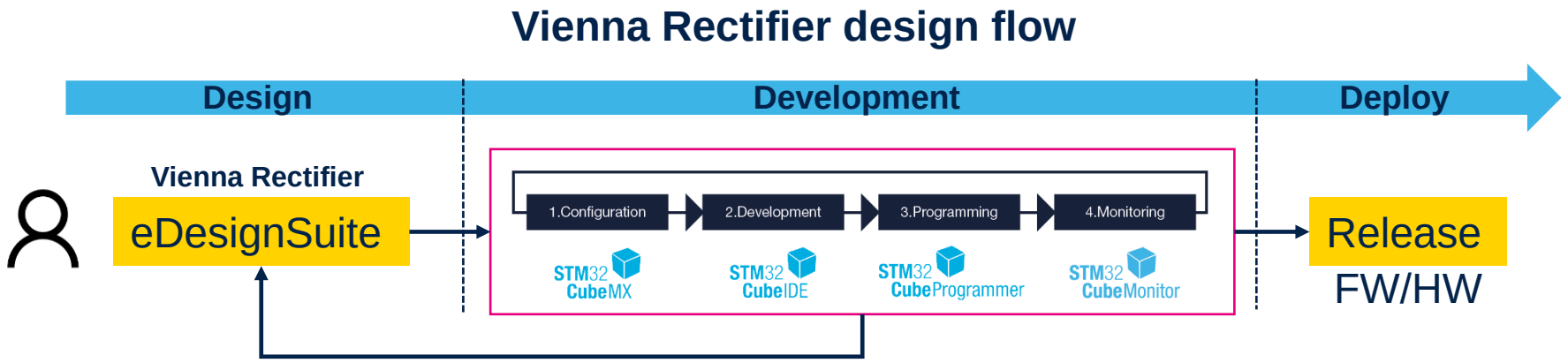




STM32G4ontrol board

life.augmented

Digital power conversion for Vienna Rectifier

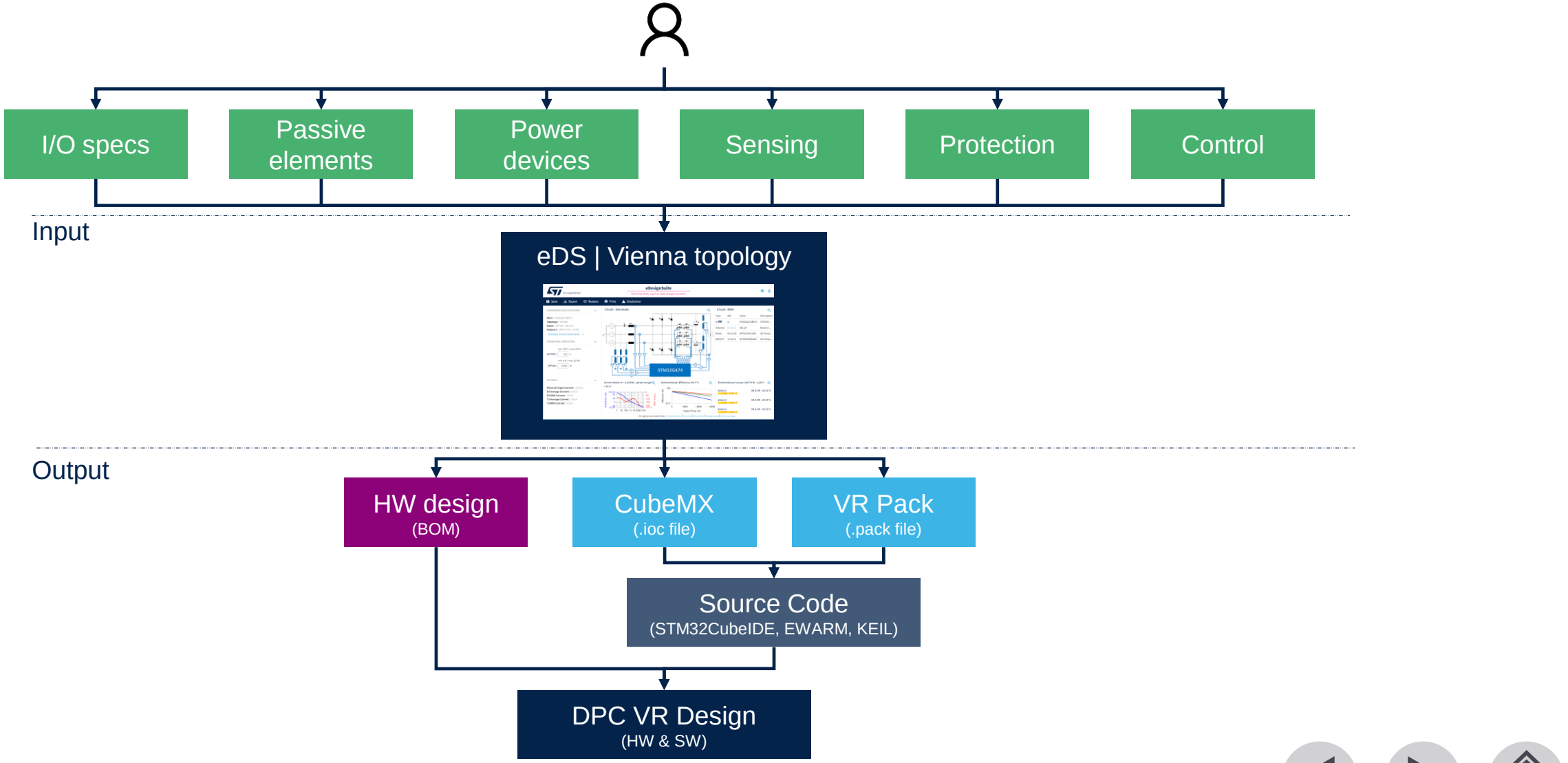


Digital Power - Vienna Rectifier in eDesignSuite

- New approach to Digital Power Conversion software architecture
- For digital power applications based on Vienna Rectifier topology it provides:
  - electrical schematic
  - BOM and Analysis Diagrams
  - STM32G4 Firmware Package code according to the Digital Power Software Architecture

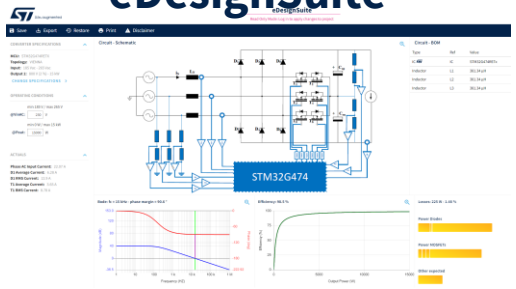
life.augmented

eDesignSuite design flow



Vienna Rectifier STM32Cube design flow

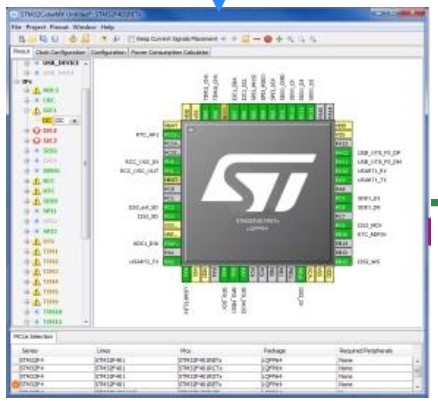
eDesignSuite



DPC Vienna
.ioc file

DPC Vienna
.pack file

STM32CubeMX



STM32 CubeIDE

IAR SYSTEMS

arm KEIL

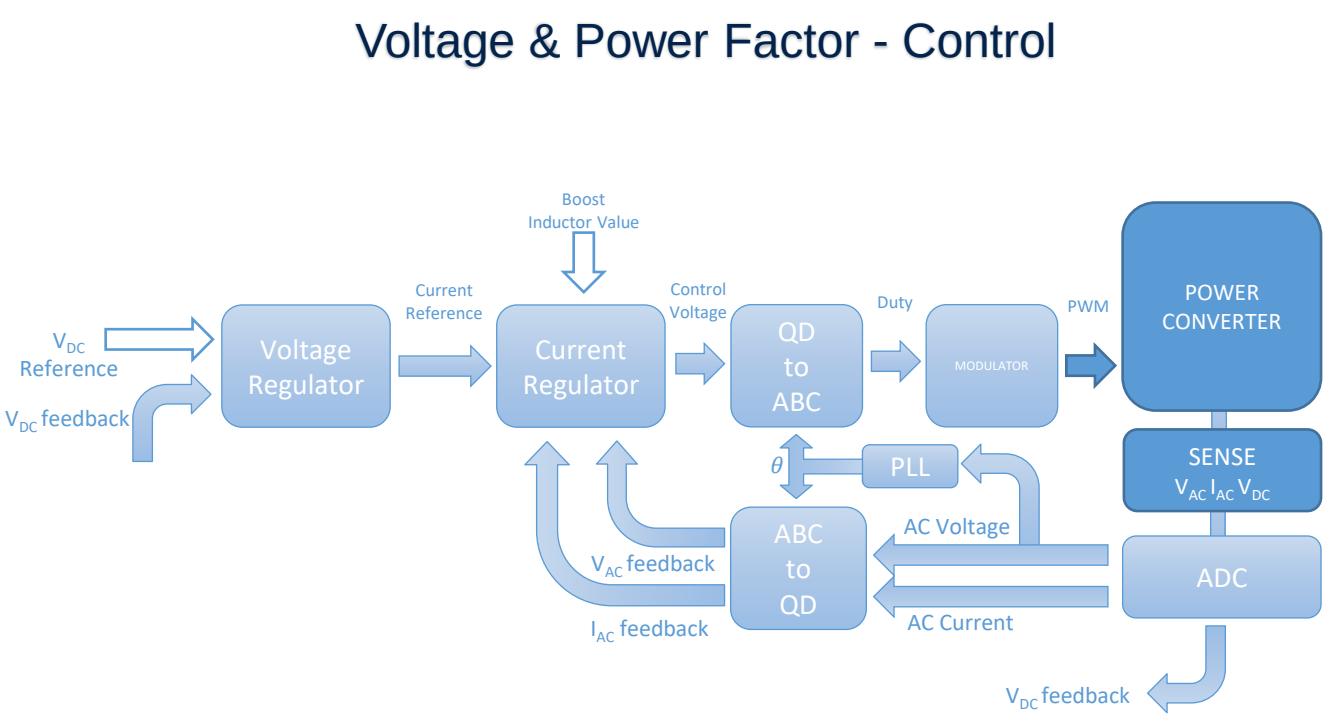
Project files

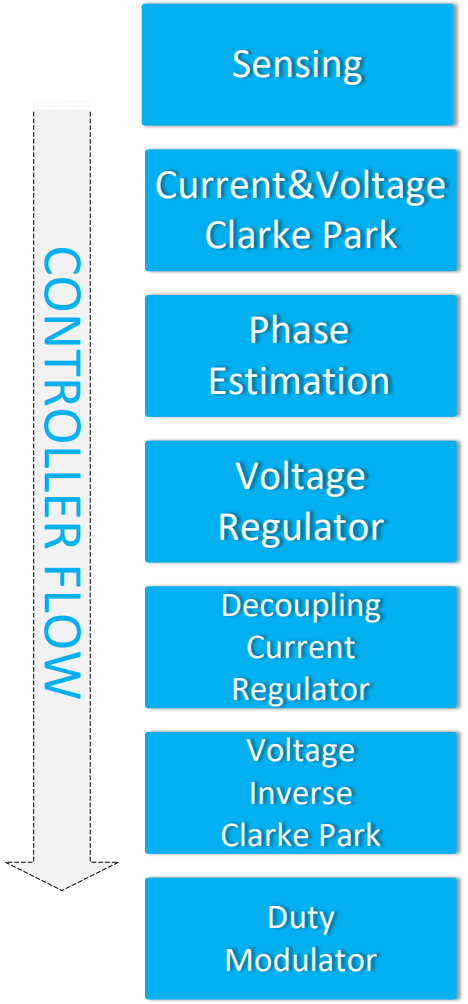
Files.c

Files.h

life.augmented

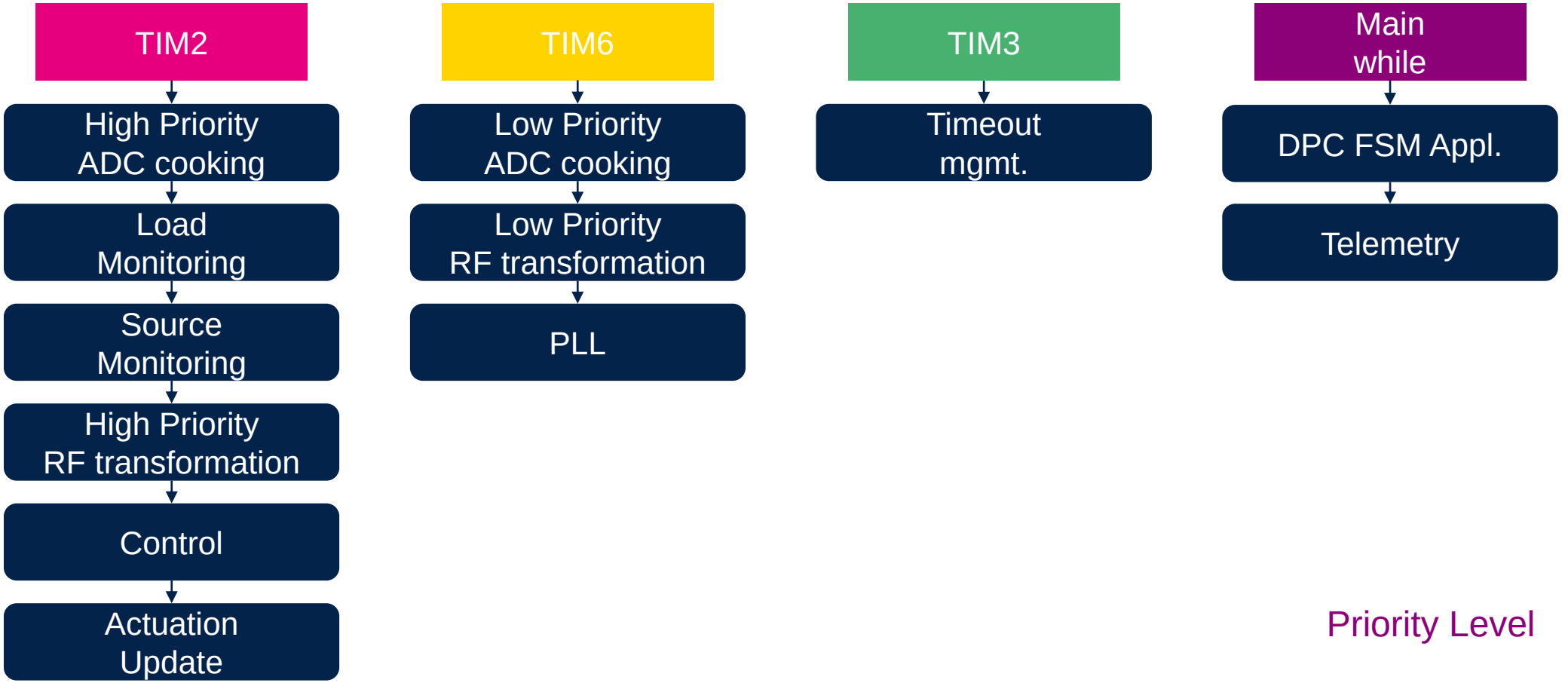
Control implementation





life.augmented

STM32G4 control implementation



Mixed signal MCUs for digital power conversion

STM32G4 mixed signal MCU

- High performance Arm® Cortex®-M4 at 170 MHz and math accelerators
- Rich integrated analog and digital peripherals
- STM32Cube ecosystem and extended digital power conversion ecosystem to simplify development

life.augmented

STM32G4 mixed-signal MCU for digital power conversion

High performance
ARM Cortex-M4 + FPU @ 170Mhz
ART Accelerator, Routine Booster(CCM)
Math Accelerators (FMAC, CORDIC)

Rich Analog Peripherals
X7 comparators19ns prop delay
x5 12-bit ADC 4MSPS
X7 12-bit DAC 15 Msps

High-resolution Timer
12 channels up to 184 ps resolution
Flexible PWMs & event handler
Various topologies (triple interleaved LLC)

STM32G4

High robustness
Highly immunity to fast transients
Robust IOs against negative injections

Safety
Checksum by hardware
ECC on Flash, Parity on RAM
FuSa SW library (SIL)

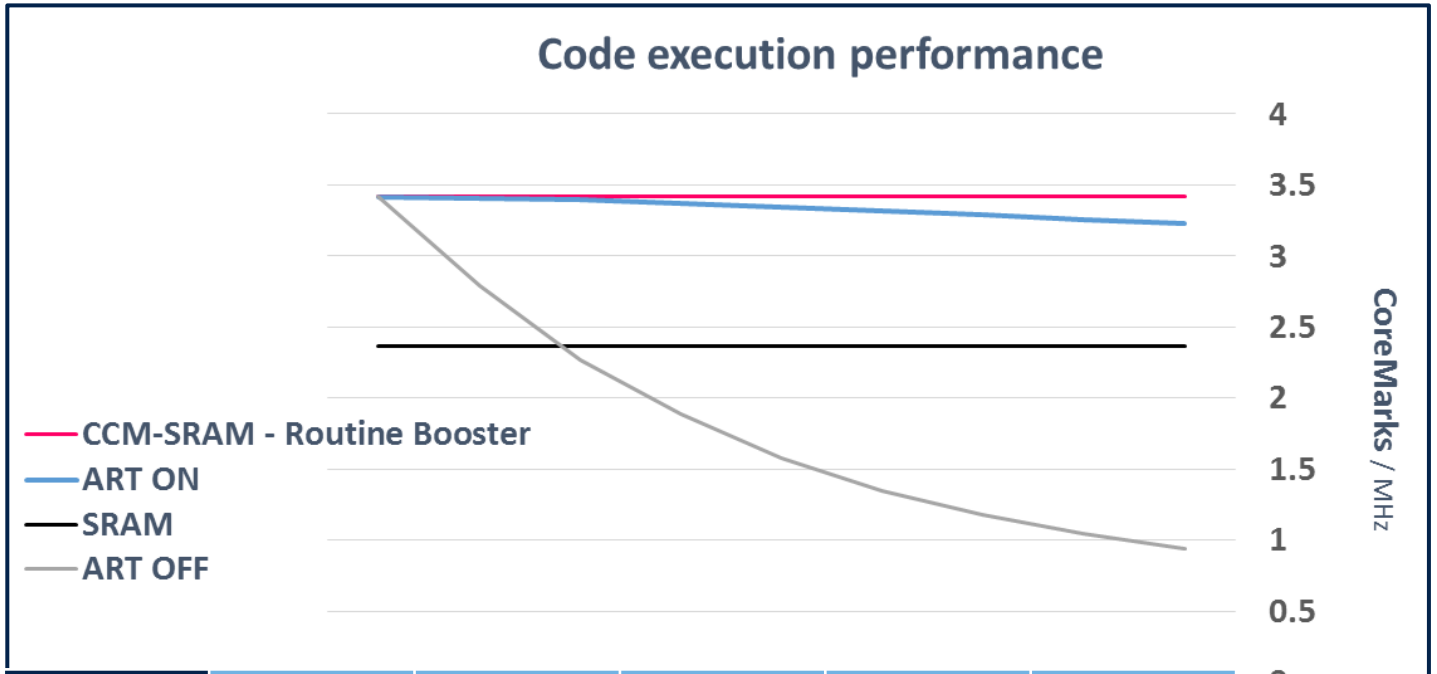
High temperature
from -40°C up to +125°C

Digital Power Ecosystem
Digital power supply boards, examples
Power factor correction boards, examples
Biricha Digital WDS & PLD design tools
STM32Cube tools & firmware

life.augmented

STM32**G4**

High performance CPU with accelerators



Number of Wait States	0	1	2	3	4
CPU Clock (MHz)	34	68	102	136	170

Arm Cortex-M4 with **FPU**

Up to 170 MHz CPU frequency

Up to 213 DMIPS and 569 CoreMark® results

3 different **HW accelerators**:

- **ART accelerator** (~dynamic cache) → Full code acceleration (average)
- **Routine Booster** CCM-SRAM (~static cache) → determinism preserved
- **Mathematical** (Cordic + FMAC)

life.augmented

STM32G4

Mathematical accelerators

1. Cordic (Trigo)

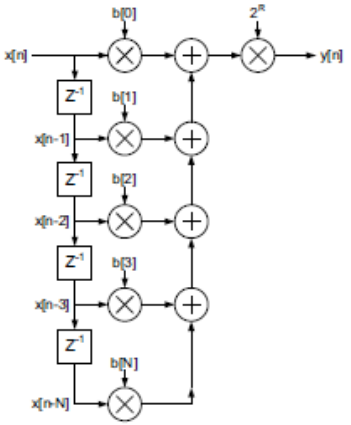
- Very helpful for Field Oriented Motor Control method (FOC)

- Vector rotation (polar to rectangular): Sin, Cos
- Vector translation (rectangular to polar): Atan2, Modulus
- Sinh, Cosh, Exp
- Atan, Atanh
- Square root
- Ln

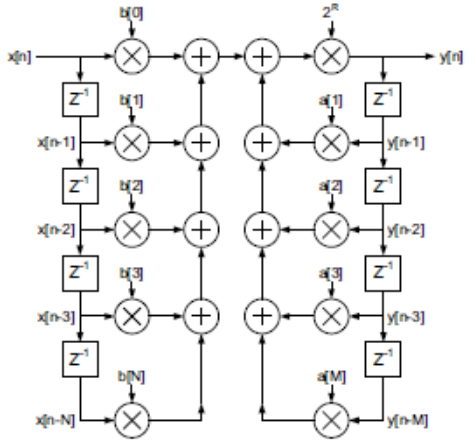
2. Filter Math Accelerator (FMAC)

- Can be used to create
  - 3p3z Compensator (→ Digital power)
  - Sigma Delta modulator
  - Noise Shaper

FIR filter



IIR filter



life.augmented

STM32**G4**

Rich advanced analog peripherals

ADC (up to 5)	**Values**
Topology	**SAR 12-bit** + HW oversampling → **16-bit**
Sampling rate	Up to **4 Msps**
Input	Single-ended and differential
Offset and Gain compensation	Auto calibration to reduce gain and offset

DAC (up to 7)	**Values**
Sampling rate	**15 Msps** (internal) 1 Msps (from buffered output)
Settling time	16 ns

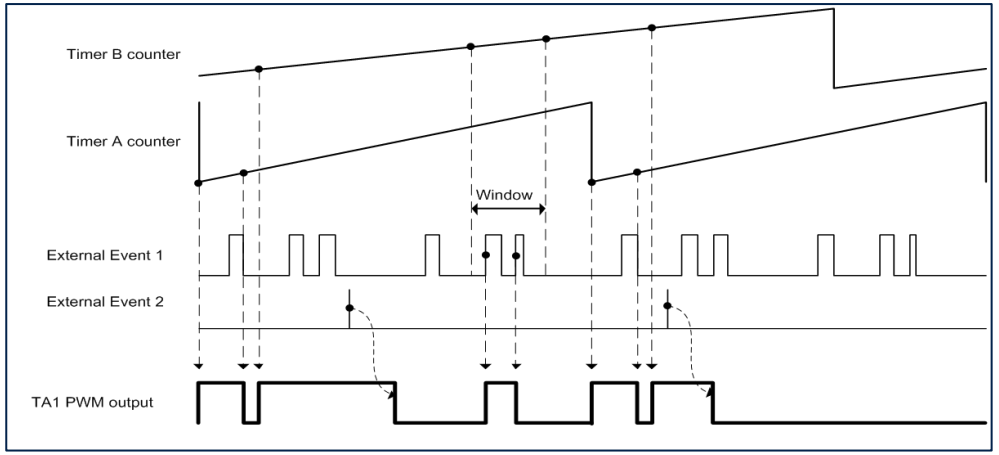
Op-Amp (up to 6)	**Values**
GBW	**13 MHz**
Slew rate	**45 V/µs**
Offset	3 mV over full T° range 1.5 mV @ 25°C
PGA Gain (accuracy)	2, 4, 8, 16, -1,-3,-7,-15 **(1%)** 32, 64, -31,-63 (2%)

Comparator (up to 7)	**Values**
Power supply	1.62 .. 3.6 V
Propagation delay	**16.7 ns**
Offset	-6 .. +2 mV
Hysteresis	8 steps: 0, 9, 18, 27, 36, 45, 54, 63 mV

High-resolution timer peripheral (HRTIM)

High resolution PWM

- 12 channels with 184ps resolution on frequency and duty cycle
- 184ps is equivalent to 5.4GHz timer clock



Flexible PWM generation

- 7x independent time base to create various shape of PWM
- 6x complementary pair PWM outputs
- Up to 32 set/reset transition per PWM period thx to the built-in crossbar
- Master/Slave configuration for multi phase converter

Multiple Event handler

- 6x Digital and Analog fault input
- 10x events cycle to cycle current control or PWM restart (constant Ton/Toff)
- Blanking, windowing and digital filter

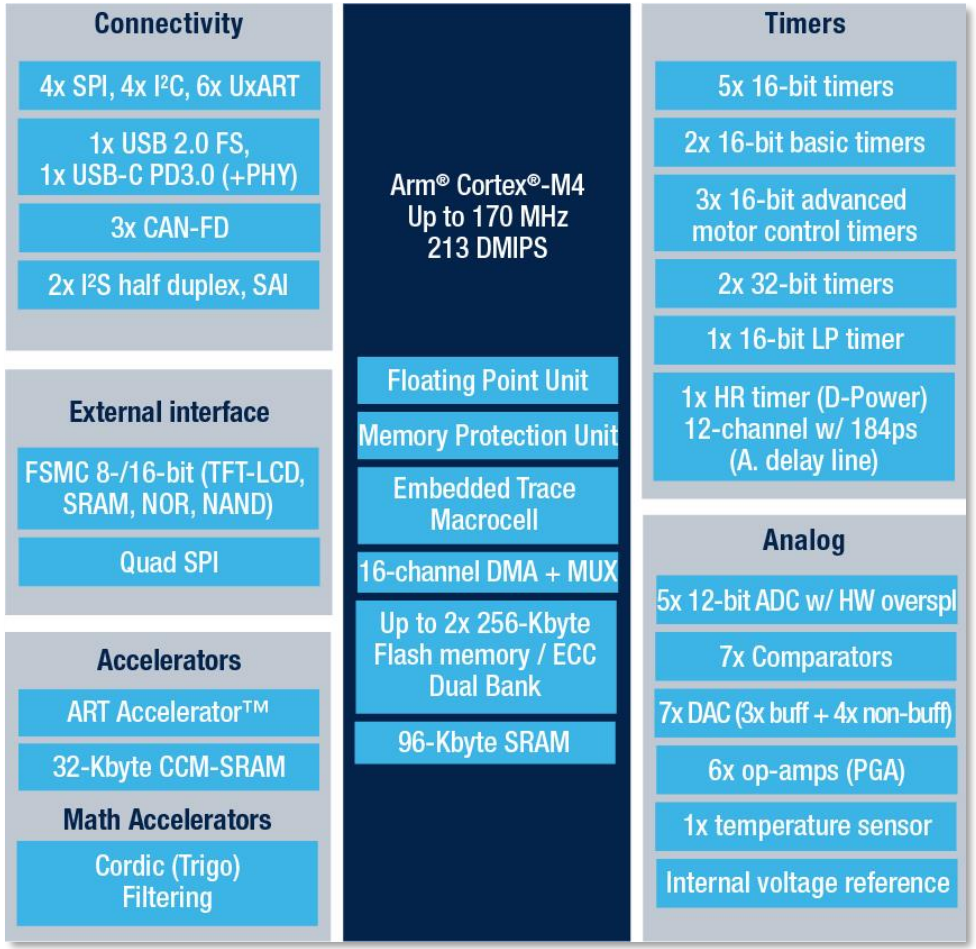
12 independent channels

- Any topology supported from 1x 12 PWM (triple interleaved LLC (server application) up to 12x1 PWM (multiple independent buck converters (lighting)

life.augmented

STM32G474 block diagram

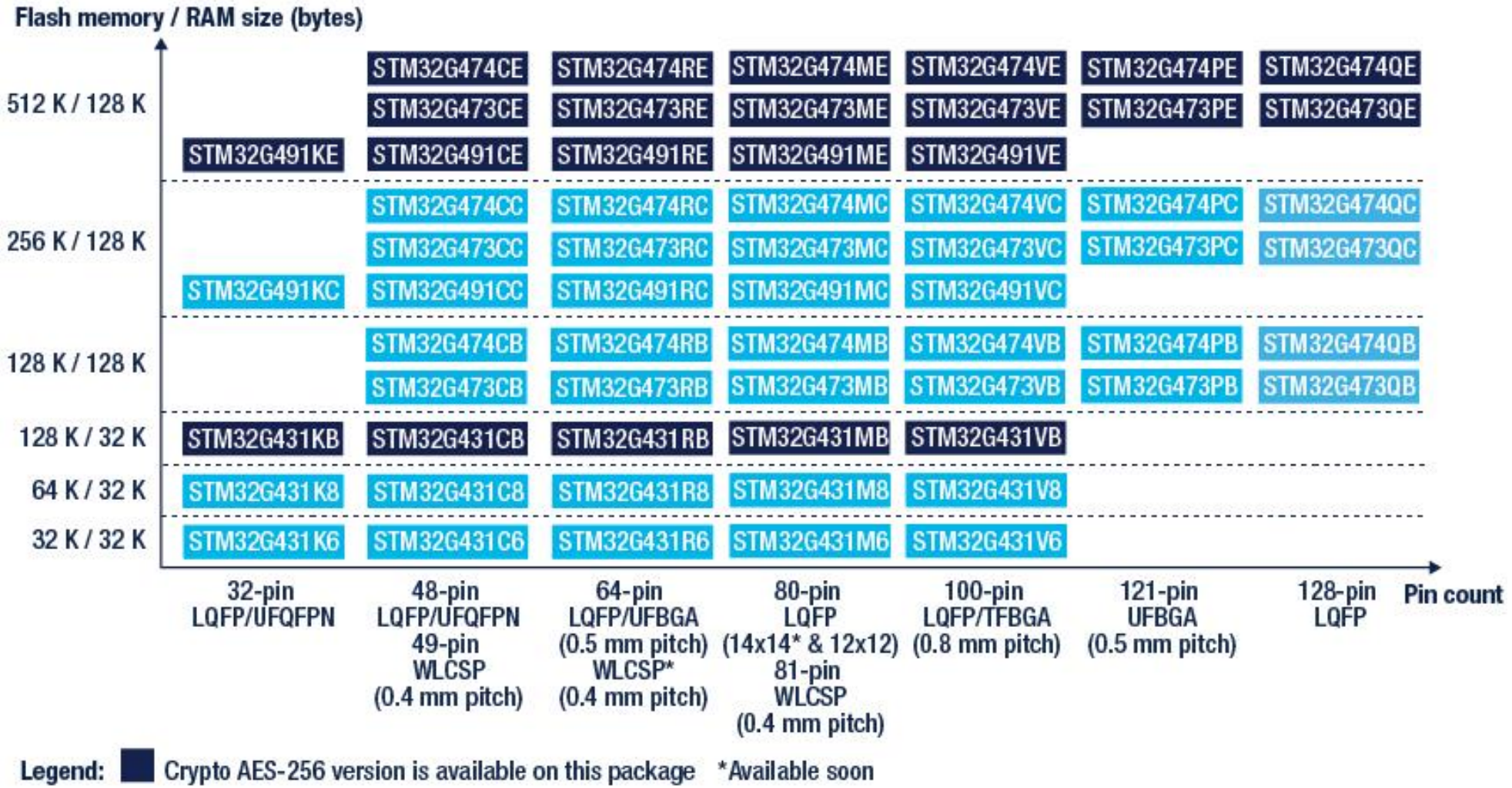
- 32-bit Arm Cortex-M4 core with FPU
- ART + CCM-SRAM + Mathematic Accelerators
- Dual Bank Flash with ECC
- SRAM with Parity bit
- +/- 1% internal clock
- 1.72 to 3.6V power supply
- Up to 125°C



- High resolution timer
- 3x Advanced Motor Control timers
- Rich Advanced Analog
- 3x CAN Flexible Data rate
- USB-C Power Delivery3.0
- Advanced Security and Safety features
- Robustness: highest level 5 / FTB/ESD - IEC 61000-4-4

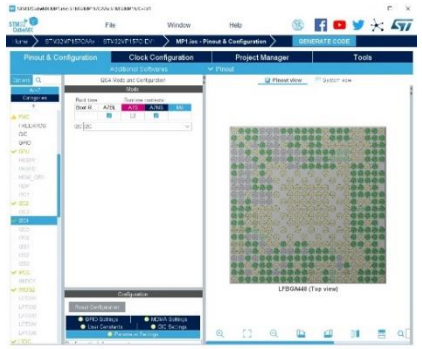
life.augmented

STM32G4 portfolio



life.augmented

STM32G4 software tools



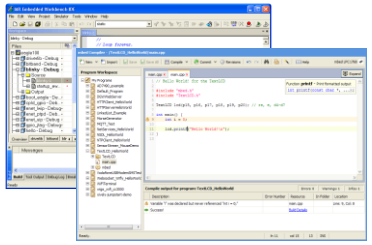
STM32 CubeMX

arm KEIL

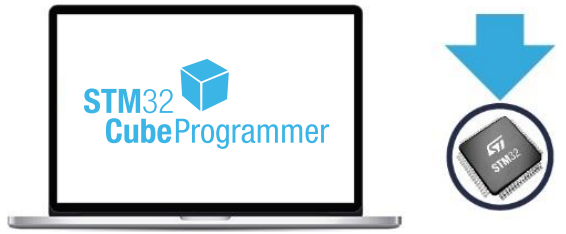
IAR SYSTEMS

eclipse

STM32 CubeIDE



All-in-one STM32 programming tool
Multi-mode, user-friendly



STM32CubeMX

STM32CubeMX

- Configure and generate Code
- Conflicts solver

IDEs
Compile and Debug

Flexible Solutions

- Partners IDE, like IAR and Keil
- Free IDE based on Eclipse, like STM32CubeIDE

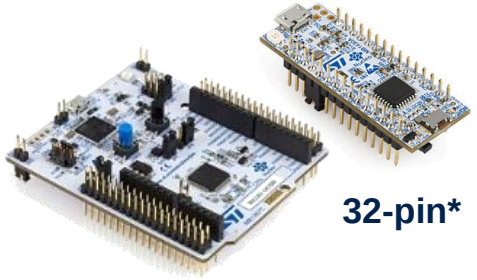
STM32 Programming Tool

STM32CubeProgrammer

- Flash and/or system memory
- GUI or command line interface

life.augmented

STM32G4 hardware solutions



32-pin*

64-pin

STM32 Nucleo

Flexible prototyping

- NUCLEO-G431RB
- NUCLEO-G474RE
- NUCLEO-G431KB*
- NUCLEO-G491RE

Evaluation boards

Full feature STM32G4 evaluation

- STM32G484E-EVAL
- STM32G474E-EVAL
- STM32G474E-EVAL1

Motor Control Pack

Full feature for Motor Control and Analog

- P-NUCLEO-IHM03

Discovery kits

Key feature prototyping

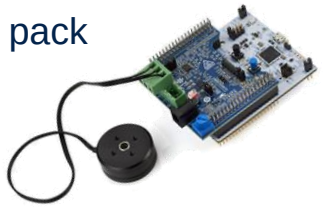
- B-G474E-DPOW1
- B-G431B-ESC1

life.augmented

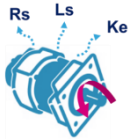
Extended ecosystems for key applications

Motor Control

- **Complete ecosystem** (HW boards, SW Development Kit (SDK), docs and trainings)
  - X-CUBE-MCSDK (v5.4)
    - Motor Control FW library based on STM32Cube HAL and LL
    - Motor control workbench: Graphical configurator of the motor control library linked with STM32CubeMx
  - P-NUCLEO-IHM03: Motor Control Nucleo pack
    - NUCLEO-G431RB Nucleo-64
    - X-NUCLEO-IHM16M1 motor driver expansion board
    - Low Voltage motor



- **State of the art algorithms** (FOC, 6-step, sensorless…)
- **Motor Profiler**: Plug and spin your motor within less than one minute



www.st.com/stm32-motor-control

Digital Power

- **Complete ecosystem** (HW boards, FW examples, SW tools, docs and trainings)
- **Dedicated HRTIM Cookbook - AN4539:** How to operate the Hi-Resolution timer in different topology
- **Digital Power training** (PSU and PFC) – based on STM32 G4 series – done in collaboration with Biricha

www.st.com/stm32-digital-power

life.augmented