Caravel + Nucleo Board

Specifications

The board required features:

- To be physically compatible to act as a hat to the ST Nucleo board using the ST morpho connectors (plug-in). This would provide test setups for characterizing IOs configuration using the Nucleo board

- Includes programmable power supply on board to test the Caravel chip at a range of power supplies

- The programmable power supply is programmed with SPI/I^2C

- It can function as a stand-alone Caravel evaluation board similar to the Caravel V4 evaluation board system

Programmable Power Supply

- A programmable power supply is required to test the chip with non-nominal supplies

- The required ranges are from $1.4V$ to $2.2V$ for $V_{1.8}$ and $3V$ to $3.6V$ for $V_{3.3}$

- Adjustable dual LDO (MIC2211) is capable of suppling from $1.25V$ to $5V$ at $150mA$ for V_{out1} and at $300mA$ for V_{out2}

- A digital potentiometer (D-POT) MCP4661 could be used with R network to dynamically tune the voltage outputs of the LDO using I^2C interface

- D-POT ($10\,k\Omega$ device) range to be used in the calculations is from $0\,k\Omega$ to $7\,k\Omega$, since its maximum resistance range at temperature corners is $8\,k\Omega$ and $12\,k\Omega$

- MCP4661 has **257 taps**

$$N = \frac{R_{MAX}}{R_{TOT}} * 256 = 179.2 \approx 179$$

$$R_{step} = \frac{R_{TOT}}{256} = 39\,\Omega$$

[2]: https://www.ti.com/lit/ug/tidu950/tidu950.pdf?ts=1661679201370&ref_url=https%253A%252F%252Fwww.google.com%252F

Resistance Calculations

- **For $V_{1.8}$,**

$$V_{out1min} = 1.4V \qquad V_{out1max} = 2.2V$$

$$R_{LSmax} = 3\ k\Omega \qquad V_{Ref} = 1.25V$$

$$V_{out1min} = V_{Ref}\left(1 + \frac{R_1}{R_{LSmax}}\right) \qquad \therefore R_1 = R_{LSmax}\left(\frac{V_{out1min}}{V_{Ref}} - 1\right) = 360\ \Omega$$

$$R_{LSmin} = R_1 * \left(\frac{V_{Ref}}{V_{out1max} - V_{Ref}}\right) = 473.7\Omega$$

$$R_{DPmin} = 0\ k\Omega \qquad R_{DPmax} = 7\ k\Omega$$

$$R_{LSmin} = \frac{R_2 * (R_3 + R_{DPmin})}{R_2 + R_3 + R_{DPmin}} = \frac{R_2 * R_3}{R_2 + R_3} \qquad R_{LSmax} = \frac{R_2 * (R_3 + R_{DPmax})}{R_2 + R_3 + R_{DPmax}}$$
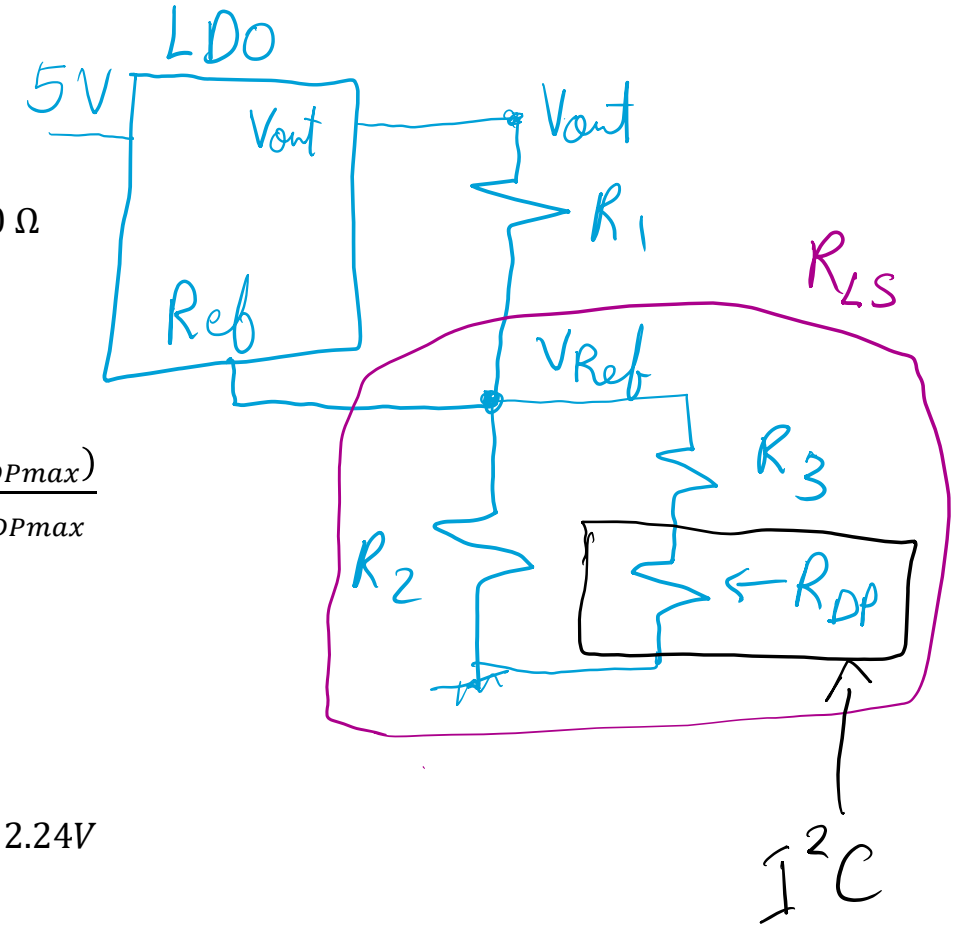
Assume $R_3 = 500\ \Omega$,

$$R_2 = \frac{R_{LSmax} * (R_3 + R_{DPmax})}{(R_3 + R_{DPmax}) - R_{LSmax}} = 5\ k\Omega$$

Verify:

$$R_{LSmin} = \frac{R_2 * R_3}{R_2 + R_3} = 455\ \Omega \qquad \therefore V_{out2max} = V_{Ref}\left(1 + \frac{R_1}{R_{LSmin}}\right) = 2.24V$$

Notes:

- V_{Ref} is from the adjustable dual LDO (MIC2211) datasheet

- R_{LSmax} is set to ensure loop stability, not sure of the basis of this value

Resistance Calculations

- For $V_{3.3}$,

$$V_{out2min} = 3V \qquad V_{out2max} = 3.6V$$
$$R_{LSmax} = 3\ k\Omega \qquad V_{Ref} = 1.25V$$

$$V_{out2min} = V_{Ref}\left(1 + \frac{R_1}{R_{LSmax}}\right) \qquad \therefore R_1 = R_{LSmax}\left(\frac{V_{out2min}}{V_{Ref}} - 1\right) = 4.2\ k\Omega$$

$$R_{LSmin} = R_1 * \left(\frac{V_{Ref}}{V_{out2max} - V_{Ref}}\right) = 2.2k\Omega$$

$$R_{DPmin} = 0\ k\Omega \qquad R_{DPmax} = 7\ k\Omega$$

$$R_{LSmin} = \frac{R_2 * (R_3 + R_{DPmin})}{R_2 + R_3 + R_{DPmin}} = \frac{R_2 * R_3}{R_2 + R_3} \qquad R_{LSmax} = \frac{R_2 * (R_3 + R_{DPmax})}{R_2 + R_3 + R_{DPmax}}$$

Assume $R_3 = 5\ k\Omega$,

$$R_2 = \frac{R_{LSmax} * (R_3 + R_{DPmax})}{(R_3 + R_{DPmax}) - R_{LSmax}} = 4\ k\Omega$$

Verify:

$$R_{LSmin} = \frac{R_2 * R_3}{R_2 + R_3} = 2.2\ k\Omega \qquad \therefore V_{out2max} = V_{Ref}\left(1 + \frac{R_1}{R_{LSmin}}\right) = 3.64V$$

Notes:

- V_{Ref} is from the dual LDO (MIC2211) datasheet
- R_{LSmax} is set to ensure loop stability in the TI note, not sure of the basis of this value

Resistance Calculations

- For nominal supplies:

$$V_{out1} = 1.8V \qquad V_{out2} = 3.3V$$

$$R_{LS} = R_1 * \left(\frac{V_{Ref}}{V_{out} - V_{Ref}} \right)$$

$$\therefore R_{LS1} = 818.2 \ \Omega \qquad \therefore R_{LS2} = 2.6 \ k\Omega$$

$$R_{LS} = \frac{R_2 * (R_3 + R_{DP})}{R_2 + R_3 + R_{DP}} \qquad \therefore R_{DP} = \frac{R_{LS} * (R_2 + R_3) - R_2 R_3}{R_2 - R_{LS}}$$

$$\therefore R_{DP1} = 478 \ \Omega \qquad \therefore R_{DP2} = 2.4 k\Omega$$

$$R_{DP} = \frac{R_{TOT} N}{256} + R_W \qquad \therefore N = (R_{DP} - R_W) * \frac{256}{R_{TOT}}$$

$$R_W = 75 \ \Omega \qquad R_{TOT} = 10 \ k\Omega$$

$$\therefore N_1 = 10.3 \approx 11 \ (Bh) \qquad \therefore N_2 = 59.5 \approx 60 \ (3Ch)$$

Resistors

Output	Resistor	Computed Value	Size 0805 1%
V_{out1}	R_1	360 Ω	360 Ω
	R_2	5 $k\Omega$	4.99 $k\Omega$
	R_3	500 Ω	499 Ω
V_{out2}	R_1	4.2 $k\Omega$	4.22 $k\Omega$
	R_2	4 $k\Omega$	4.02 $k\Omega$
	R_3	5 $k\Omega$	4.99 $k\Omega$

Notes:

- MIC2211 datasheet recommends the resistor values should be between 100kΩ and 500kΩ to prevent compromising the low quiescent current performance. This can't be achieved with the R_{LSmax} assumption
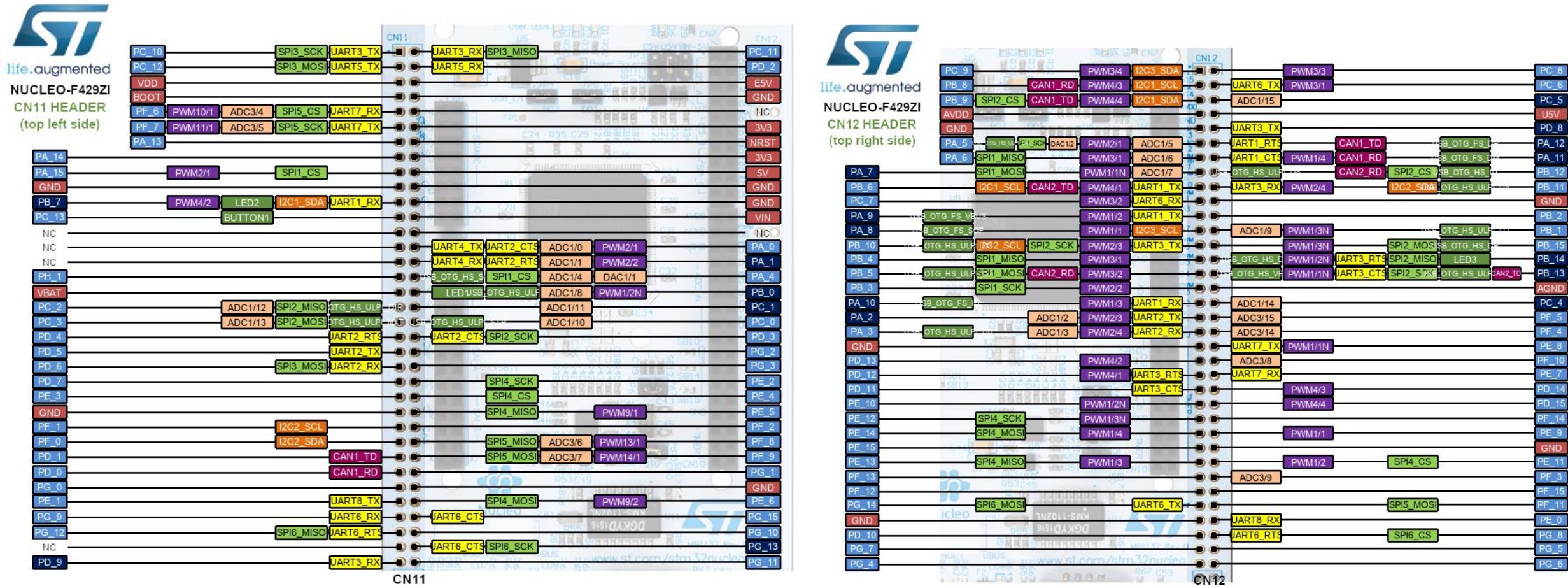
Caravel Board V4 Block Diagram
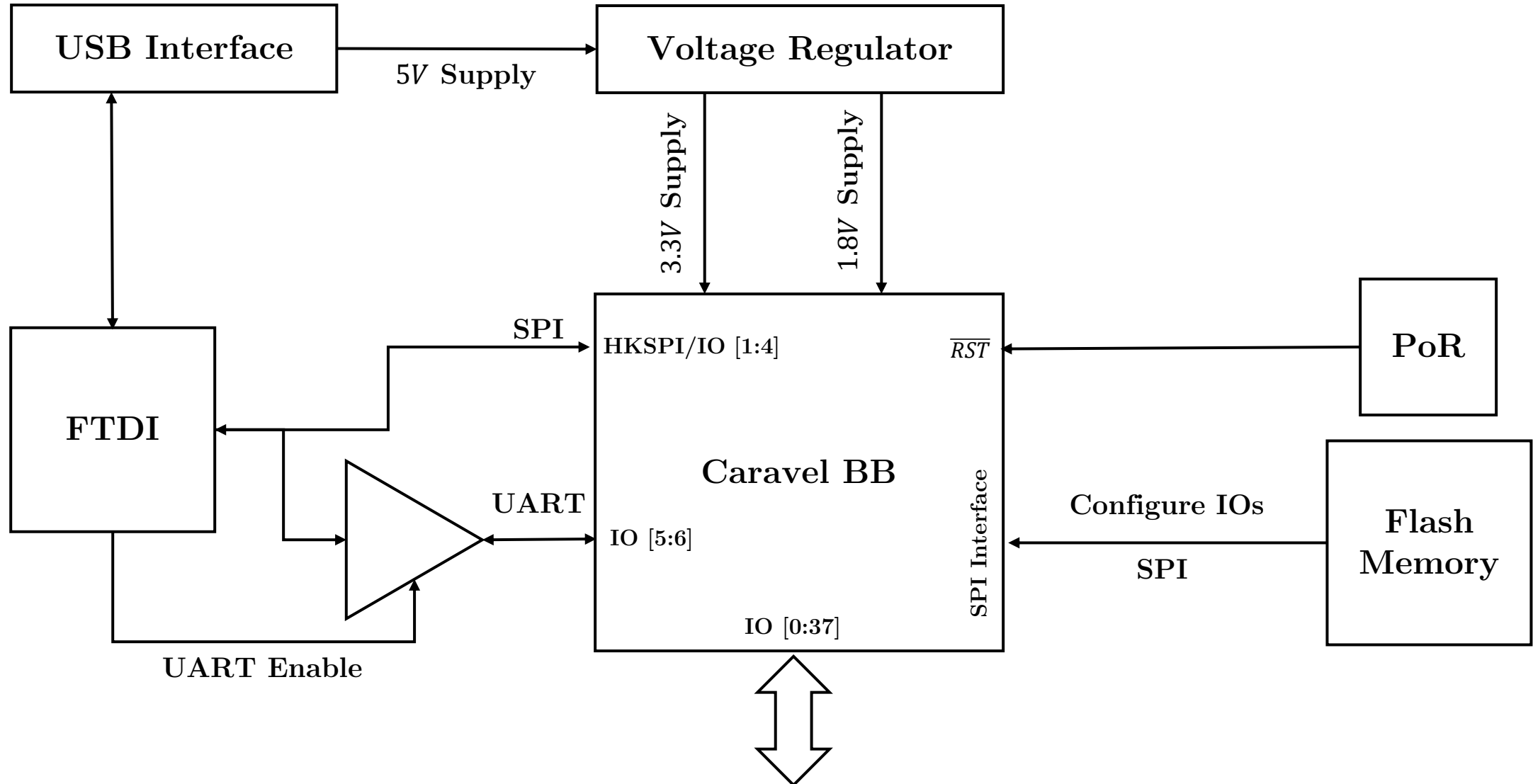
Nucleo Board: Interface with Caravel

Nucleo Board: NUCLEO144-F429ZI

- $CN4$ jumpers in ST-Link part is used to program STM32 MCU

- The board is used as a test setup for characterizing the I/O configuration

- The board has a **3.3V Regulator** (Max $500mA$)

- Default clock supply is $8\,MHz$ from ST-Link on $PH0$

- Caravel SPI/HKSPI interface could be connected to STM32 MCU SPI interfaces

- Caravel UART interface could be connected to STM32 MCU interface

- $PA13$ and $PA14$ are shared with SWD signals connected to ST-LINK. If ST-LINK part is not cut, it is not recommended to use them as I/Os.

Nucleo Board: ST Morpho Connectors

[1]: https://os.mbed.com/platforms/ST-Nucleo-F429ZI/#board-pinout

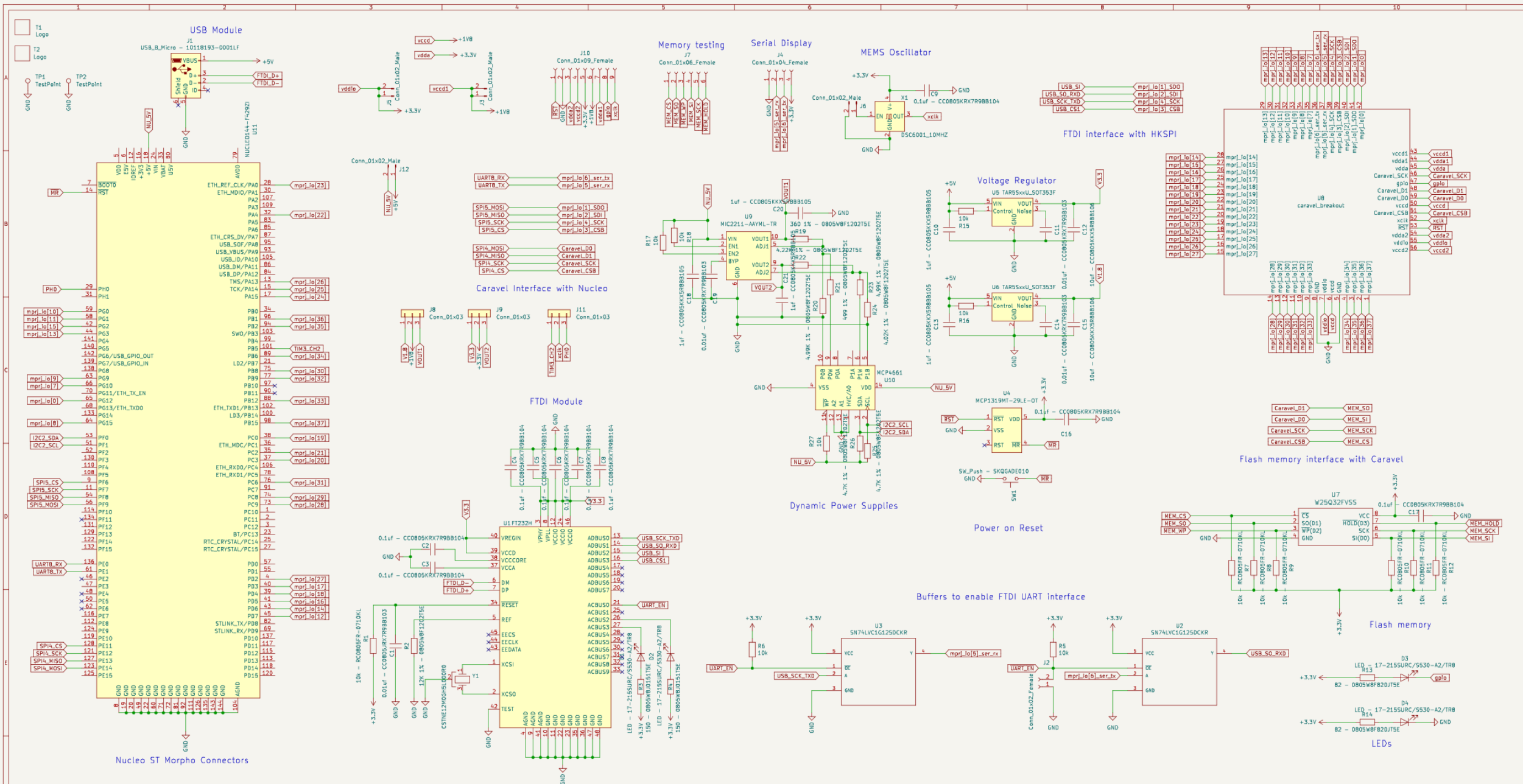# Caravel + Nucleo Board Block Diagram
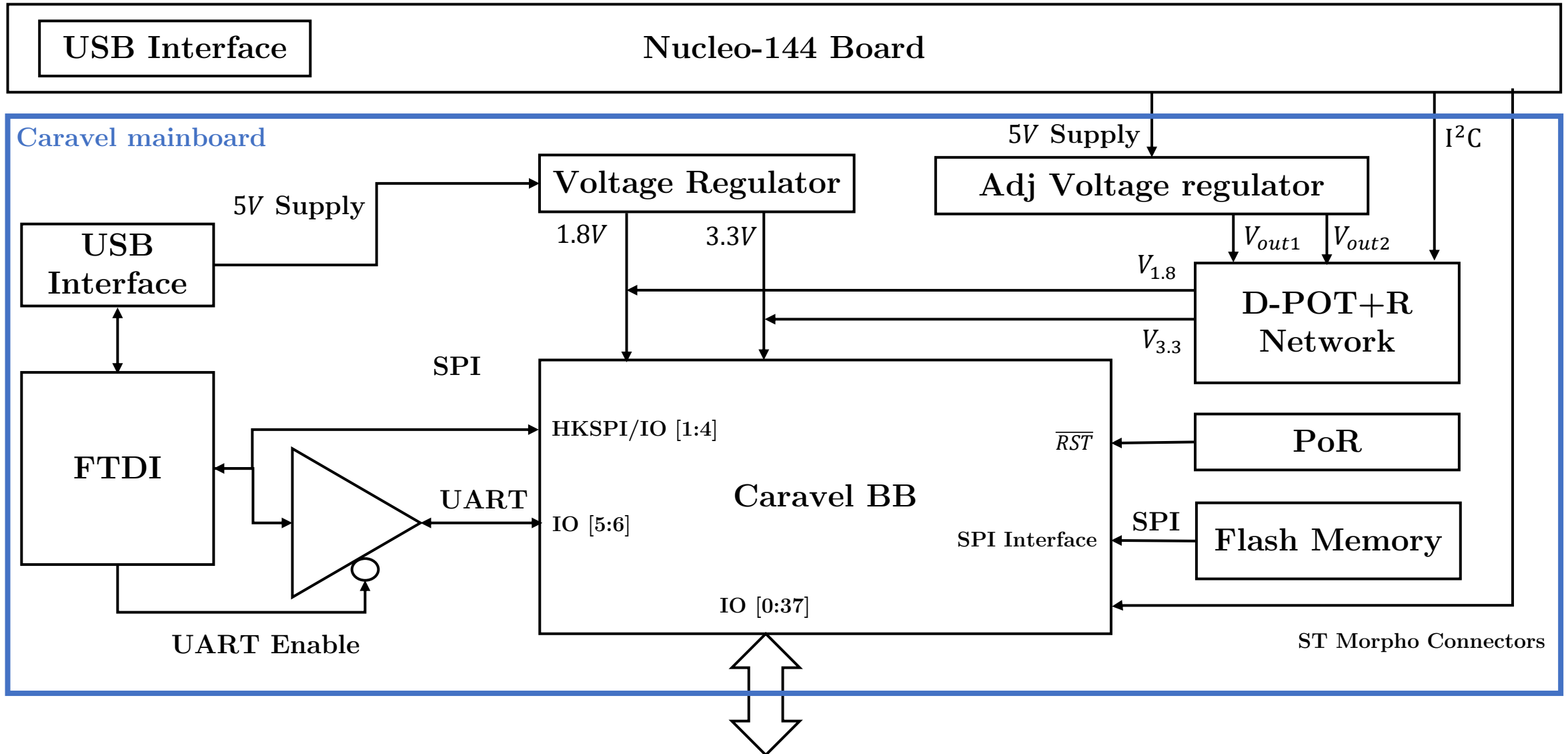
Caravel + Nucleo Board Schematic

Notes:

- Default clock is $8\,MHz$ on $PH0$ and a timer could be used to supply the clock to caravel as a PWM signal for example, $TIM3\_CH2$ on $PB5$

- Caravel SPI connected to SPI4 ($PE2\,PE4{:}PE6$) and HKSPI to SPI5 ($PF6{:}PF9$)

- Caravel UART connected to UART8 ($PE0{:}PE1$)

- Nucleo board $\overline{RST}$ connected to the manual reset $\overline{MR}$ (on board reset button) of the PoR circuit

- Caravel remaining 32 I/Os connected to pins that have no conflict on them and are in the order of the breakout board pinout

- The supplies are connected to external pin header with $gpio$, $xclk$ and $\overline{RST}$

- Nucleo Board: NUCLEO144-F429ZI

- Cravel Breakout Board: V2 breakout board with Caravel WCSP chip

Caravel + Nucleo Board Schematic

Caravel + Nucleo Board Schematic

Caravel + Nucleo Board Components

Component	Reference	Description
MCP1319MT-29LE-OT	U4	Power on Reset (PoR) circuit with internal pull-up resistors
TAR5SxxU_SOT353F	U5 & U6	Fixed voltage regulators that provide $1.8V$ and $3.3V$. The footprint is the same for a wide range of LDO devices from 1.5V to 5V which allows installing $1.6V$ LDO in place of the $1.8V$ for example
MIC2211-AAYML-TR	U9	Adjustable voltage regulator that is used to provide a programmable power supply by adjusting the resistors of each output. It is supplied with $5V$ from the Nucelo Board
MCP4661	U10	Digital Potentiometer that is programmed using I^2C interface to provide desired resistive loads for U9 to achieve the programmable power supply. It also has an EEPROM which allows stand-alone operation after saving the desired values. It is supplied with $5V$ from the Nucelo Board
NUCLEO144-F429ZI	U11	The Nucleo-144-F429ZI board ST Morpho connectors that has 144 pins interfacing with STM32 MCU

Caravel + Nucleo Pinout

Caravel BB Pin	ST Morpho Pin		Caravel BB Pin	ST Morpho Pin
1: io[37]	98: PB15		15: io[27]	4: PD2
2: io[36]	96: PB1		16: io[26]	13: PA13
3: io[35]	94: PB2		17: io[25]	15: PA14
4: io[34]	89: PB6		18: io[24]	17: PA15
5: GND	GND		19: io[23]	28: PA0
6: vccd	-		20: io[22]	32: PA4
7: vddio	-		21: io[21]	35: PC2
8: GND	GND		22: io[20]	37: PC3
9: io[33]	88: PB12		23: io[19]	38: PC0
10: io[32]	77: PB9		24: io[18]	39: PD4
11: io[31]	76: PC6		25: io[17]	40: PD3
12: io[30]	75: PB8		26: io[16]	41: PD5
13: io[29]	74: PC8		27: io[15]	42: PG2
14: io[28]	73: PC9		28: io[14]	43: PD6

Caravel + Nucleo Pinout

Caravel BB Pin	ST Morpho Pin	Caravel BB Pin	ST Morpho Pin
29: io[13]	44: PG3	43: vccd1	-
30: io[12]	45: PD7	44: vdda1	-
31: io[11]	58: PG1	45: vdda	-
32: io[10]	59: PG0	46: Caravel/SCK	121: PE12
33: io[9]	63: PG9	47: gpio	-
34: io[8]	64: PG15	48: Caravel/D1	127: PE13
35: io[7]	66: PG10	49: Caravel/D0	123: PE14
36: io[6]/tx	136:PE0	50: vccd	-
37: io[5]/rx	61: PE1	51: Caravel/CSB	128: PE11
38: io[4]/SCK	11: PF7	52: xclk	-
39: io[3]/CSB	9: PF6	53: NRST	-
40: io[2]/SDI	54: PF8	54: vdda2	-
41: io[1]/SDO	56: PF9	55: vddio	-
42: io[0]	65: PG12	56: vccd2	-

Caravel + Nucleo Board Modes

MAIN mode:

- The board is programmed through the USB module communicating with the FTDI.

- The $5V$ supply is provided from the USB module to power the fixed voltage supplies (U5 and U6) which in turn power up the other system components except for the programmable power supply.

- J8 and J9 are set to connect pin 2 to pin 1 ($MAIN$).

- J8 and J9 are left floating if the $3.3V$ and $1.8V$ are to be supplied externally.

- J11 is left with no connections as the clock is driven from X1 with $10MHz$ frequency.

- Other frequencies could be supported by disabling X1 through J6 and driving the clock externally.

- To reset the board, use SW1 button.

- By default, the FTDI interface with the Caravel HKSPI. To switch to the UART interface of Caravel, set $\overline{UART\_EN}$ to 0 either using J2 or the FTDI $ACBUS0$

- To use the programmable power supplies saved setting instead of the fixed voltage supplies:
    1. connect pin 2 to pin 3 on J8 and J9 (HAT).
    2. connect J12 pins to provide the $5V$ supply to U9 and U10 (short $5V$ with NU_5V).

Caravel + Nucleo Board Modes

HAT mode:

- The board acts as a hat for Nucleo-144 test setup.

- The $5V$ supply is provided from the Nucleo board to power the programmable power supply (U9 and U10) which in turn power up the other system components except for the FTDI module.

- U10 is programmed from the Nucleo using I^2C interface to provide the desired supplies

- J8 and J9 are set to connect pin 2 to pin 3 (HAT).

- The clock could be driven from the Nucleo through J11 with either of the following:
    1. connect pin 2 to pin 1 to drive it as a PWM signal generated from Timer 3.
    2. connect pin 2 to pin 3 to drive it from the default clock of the MCO output of ST-LINK with a fixed $8MHz$ frequency.

- J6 is set to disable X1 in the case of driving the clock with J11.

- To reset the board, use the B2 reset push button on the Nucleo or SW1 button.

Caravel + Nucleo Board PCB

Dimensions:
$68.072 * 92.0128 \ mm^2$