# UM2078
# User manual

## Getting started with the 24 V Intelligent Power Switch expansion board based on VPS2535H for STM32 Nucleo

### Introduction

The X-NUCLEO-IPS02A1 is a 24 V Intelligent Power Switch expansion board based on the VPS2535H for STM32 Nucleo, a double channel high-side driver made using STMicroelectronics® VIPower technology.

X-NUCLEO-IPS02A1 provides a low cost, robust and easy-to-use solution for driving grounded loads, i.e. relay replacement, heating elements, solenoid driver, LED driver, light bulb driver, pumps and fans, in STM32 Nucleo projects.

The X-NUCLEO-IPS02A1 is compatible with the Arduino™ UNO R3 connector, and supports the addition of other expansion boards with a single STM32 Nucleo board. The user can also solder the ST morpho connectors.

In the boards some test points allow the user to check and measure both analog and digital signals.

Two red LEDs show the output status; a green LED shows if the board is supplied properly.

Two X-NUCLEO-IPS02A1 boards can be plugged to drive up to 4 loads with a single STM32 Nucleo board.

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# 1 Getting started

The X-NUCLEO-IPS02A1 is a 24 V double channel Intelligent Power Switch expansion board for STM32 Nucleo, able to provide an affordable and easy-to-use solution for driving grounded loads as:

- heating elements
- relay replacements
- solenoid drivers
- LED drivers
- light bulb drivers
- pumps and fans

Up to two X-NUCLEO-IPS02A1 can be plugged on the same STM32 Nucleo board as scribed in *Section 3.2: Multi expansion board configuration*.

**Table 1. Operative ratings of the X-NUCLEO-IPS02A board**

| | | Min | Nom | Max |
|---|---|---|---|---|
| Operating Voltage range from | | 8 V | 24 V | 36 V |
| Undervoltage Shutdown | | | 3.5 V | 5 V |
| Overvoltage Shutdown Hysteresis | | | 500 mV | |
| Current limitation | | 30 A | 42 A | 55 A |
| On-state resistance (per Ch) | 25 °C | | 35 mΩ | |
| | 150 °C | | | 70 mΩ |
| Temparture Range | | -40 °C | | 150 °C |

The device VPS2535H integrates advanced protective functions and the load current limitation protects the device against overload conditions. The device latches off in case of overload or thermal shutdown.

VPS2535H is intended for driving resistive or inductive loads with one side connected to ground. VPS2535H integrates an analog current sense circuit for each output channels, which delivers a current proportional to the load current. The digital inputs are 3 V and 5 V CMOS compatible.

Follow this sequence to start your project with the board:

1. Check and configure the 0R or jumpers setting based on your configuration (see Section *Section 2: Hardware and software requirements*).
2. Plug the board to the STM32 Nucleo board through Arduino UNO R3 connector for the X-NUCLEO-IPS02A1.
3. Connect the PSU to J1 connector: 1-VBatt, 2-GND. The wires size must be appropriately selected to avoid excessive voltage drops and overheating when the board operates continuously under full load.
4. Supply the board; the LED1 (green) will be turned on
5. Develop your application using the examples provided with the firmware library, X-NUCLEO-IPS02A1, 24V Multi-purpose Dual channel Smart Power High Side Driver software expansion for STM32Cube.

Further support material is available on the VPS2535H and STM32 Nucleo web pages on www.st.com.

# 2 Hardware and software requirements

Using the STM32 Nucleo boards with the X-NUCLEO-IPS02A1 expansion board requires the following software and hardware:

- 1 x Windows PC to install the software package.
- One X-NUCLEO-IPS02A1 expansion board.
- A STM32 Nucleo board (i.e.NUCLEO-L0538, NUCLEO-F401RE).
- 1 x USB type A to Mini-B USB cable to connect the STM32 Nucleo board to the PC.
- The X-CUBE-IPS02 software package (available on www.st.com).
- 1 x external power supply able to provide the right voltage and the current capability to supply the loads.
- (optional) a terminal emulator, serial console (i.e. PuTTY) to read data via USART.

# 3 Hardware description and configuration

*Figure 1* and *Figure 2* show the position of the connectors and the jumpers respectively present in the board.

**Figure 1. Connectors position**

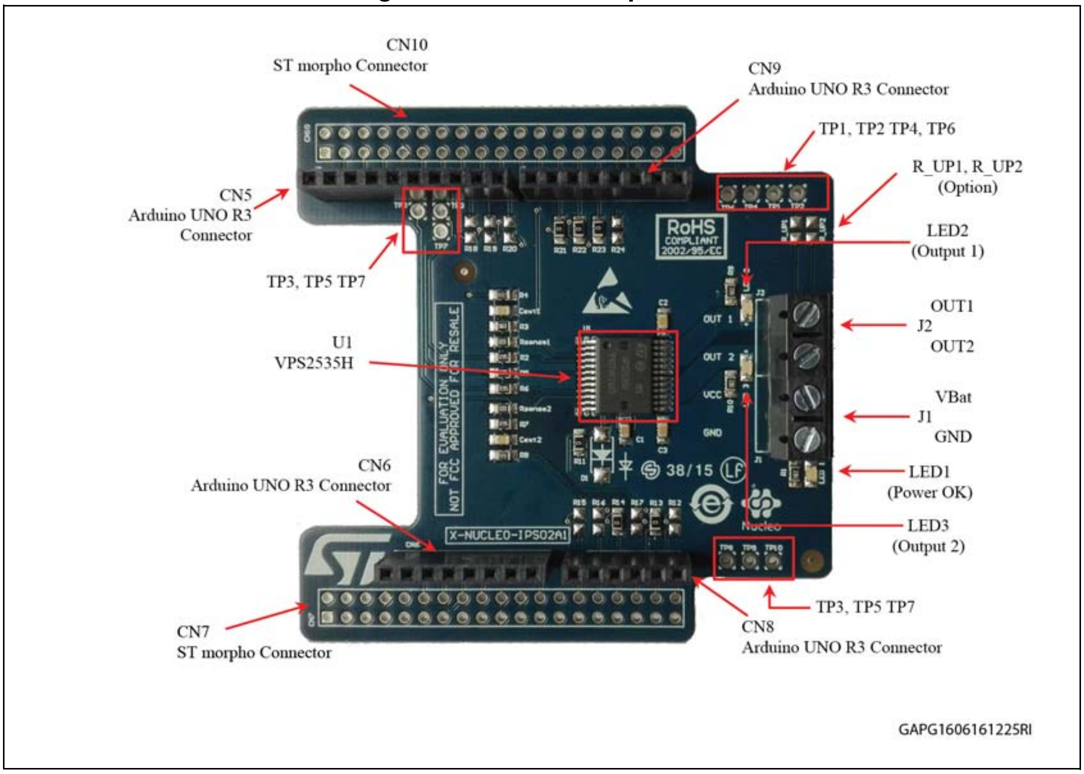
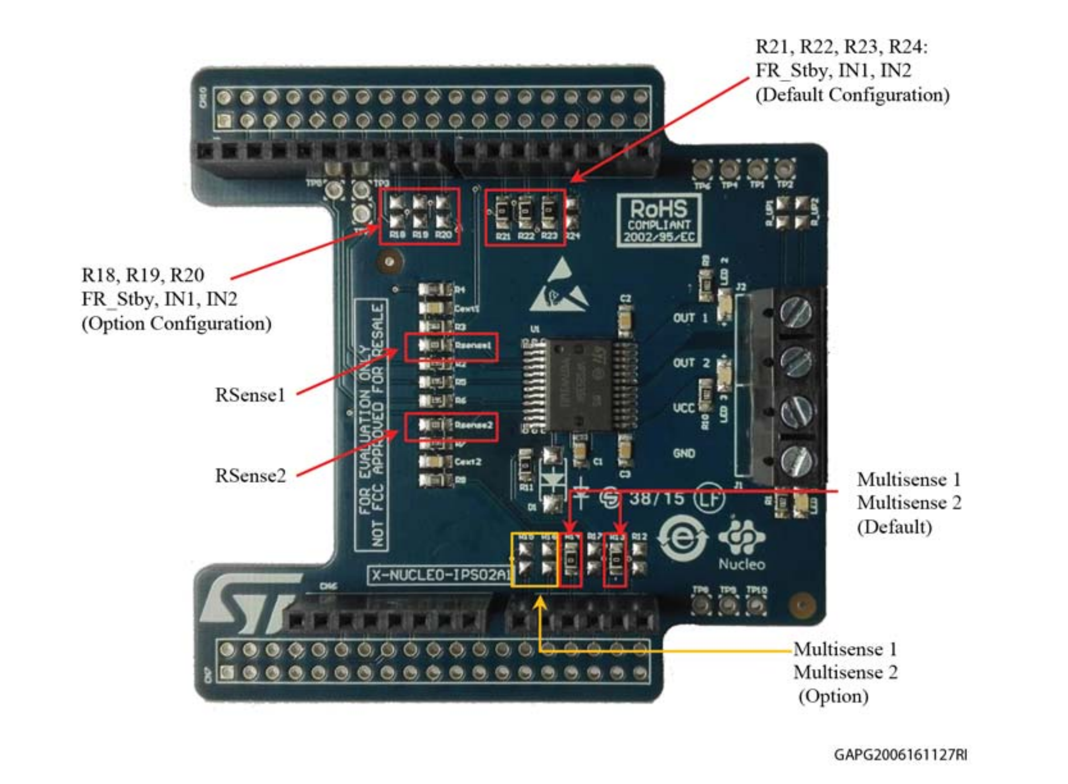


**Figure 2. Jumpers position**




Below are the pinout details for the Arduino UNO R3 and the ST morpho connectors

**Table 2. Arduino UNO R3 connector table**

| Connector | Pin(1) | Signal | Remarks |
|---|---|---|---|
| CN5 | 1 (D8) | FR_Stby (option) | Option Configuration<br>See *Section 3.1: Jumpers configurations* |
| | 2 (D9) | IN 1 (option) | |
| | 3 (D10) | IN 2 (option) | |
| CN9 | 5 (D4) | FR_Stby (Default) | Option Configuration<br>See *Section 3.1: Jumpers configurations*” |
| | 6 (D5) | IN 1 (Default) | |
| | 7 (D6) | IN 2 (Default) | |
| CN6 | 2 | +3V3 | |
| | 5 | +5V | |
| | 6, 7 | GND | |

**Table 2. Arduino UNO R3 connector table (continued)**

| Connector | Pin(1) | Signal | Remarks |
|---|---|---|---|
| CN8 | 1 (A0) | Multisense_1 (Option) | See *Section 3.1: Jumpers configurations* |
| | 2 (A1) | Multisense_2 (Option) | |
| | 3 (A2) | Multisense_1 (Default)<br>GND_Sense (Option) | |
| | 4 (A2) | Multisense_2 (Default) | |
| | 5 (A4) | GND_Sense (Option) | |

1. All the unlisted pins are not connected

**Table 3. ST morpho connector table**

| Connector | Pin | Signal | Remarks |
|---|---|---|---|
| CN7 | 12<br>16 | +3 V 3 | |
| | 14 | NRST | |
| | 18 | +5 V | |
| | 8<br>19<br>20<br>22 | GND | |
| | 28 | Multisense_1 (option) | See *Section 3.1: Jumpers configurations* |
| | 30 | Multisense_2 (option) | |
| | 32 | Multisense_1 (default)<br>GND_Sense (option) | |
| | 34 | Multisense_2 (default) | |
| | 36 | GND_Sense (option) | |
| CN10 | 9<br>20<br>32 | GND | |
| | 17 | IN 2 (option) | See *Section 3.1: Jumpers configurations* |
| | 19 | IN 1 (option) | |
| | 21 | FR_Stby (option) | |
| | 25 | IN 2 (default) | |
| | 27 | IN 1 (default) | |
| | 29 | FR_Stby (default) | |

## 3.1 Jumpers configurations

Various board configurations are possible, depending on the use cases.

The hardware configuration can be modified via the appropriate setting the R12 to R24 0R resistors as indicated *Table 4*.

**Table 4. Jumpers configurations**

| | Default configuration | Option configuration |
|---|---|---|
| R12 | Not mounted | Not mounted |
| R13 | 0 Ω | Not mounted |
| R14 | 0 Ω | Not mounted |
| R15 | Not mounted | 0 Ω |
| R16 | Not mounted | 0 Ω |
| R17 | Not mounted | Not mounted |
| R18 | Not mounted | 0 Ω |
| R19 | Not mounted | 0 Ω |
| R20 | Not mounted | 0 Ω |
| R21 | 0 Ω | Not mounted |
| R22 | 0 Ω | Not mounted |
| R23 | 0 Ω | Not mounted |
| R24 | Not mounted | Not mounted |

## 3.2 Multi expansion board configuration

Two X-NUCLEO-IPS02A1 expansion boards can be plugged on a single STM32 Nucleo board in order to drive up to the 4 loads (one expansion board for two loads is required).

The 0R jumpers present in the boards must be set as described in *Table 5*.

**Table 5. Jumpers configurations**

| | Board #1(1) | Board #2 |
|---|---|---|
| R12 | Not mounted | Not mounted |
| R13 | 0 Ω | Not mounted |
| R14 | 0 Ω | Not mounted |
| R15 | Not mounted | 0 Ω |
| R16 | Not mounted | 0 Ω |
| R17 | Not mounted | Not mounted |
| R18 | Not mounted | 0 Ω |
| R19 | Not mounted | 0 Ω |
| R20 | Not mounted | 0 Ω |

**Table 5. Jumpers configurations (continued)**

| | Board #1[(1)] | Board #2 |
|---|---|---|
| R21 | 0 Ω | Not mounted |
| R22 | 0 Ω | Not mounted |
| R23 | 0 Ω | Not mounted |

1. This is the default configuration.

*Note: If two identical boards are plugged, pay attention to avoid shortcut between the terminal blocks and to avoid shortcut between the wires connected to the two boards.*

# 4 Current sense configuration

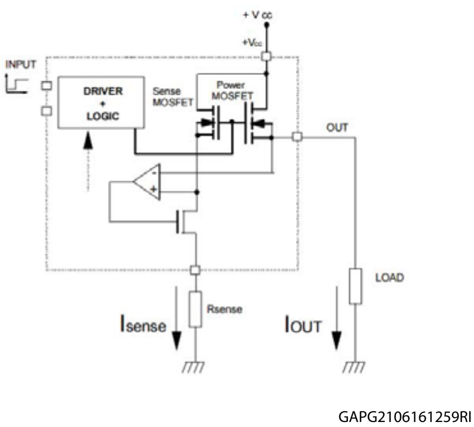
## 4.1 Introduction

The current sense feature allows measure a voltage signal that is proportional to the load current across an external resistor Rsense.

*Figure 3* shows the topology implemented in the HSD current sense circuit.

The principle of operation is to compare the currents flowing through two paths: the sense path made up of the series of a Sense-MOSFET plus the $R_{Sense}$ ($I_{Sense}$) and the power path made up of the series of Power-MOSFET plus the load (Iout).

**Figure 3. HSD current sense circuit**




The op-amp compares the voltage drop due to the load current ($V_{DS\_Power}=R_{DSon\_Power}\cdot I_{OUT}$) to the voltage drop across the Sense-MOSFET ($V_{DS\_Sense}= R_{DSon\_Sense}\cdot I_{Sense}$). During the normal working condition in on state is: $V_{DS\_Sense}=V_{DS\_Power}$, and therefore:

**Equation 1**

$$R_{DS_{POWER}} \cdot I_{LOAD} = R_{DS_{SENSE}} \cdot I_{SENSE}$$

Since:

**Equation 2**

$$V_{SENSE} = R_{DS_{SENSE}} \cdot I_{SENSE}$$

The K parameter is defined as:

**Equation 3**

$$K = \frac{R_{DS_{SENSE}}}{R_{DS_{POWER}}}$$

And the $V_{sense}$ expression is:

**Equation 4**

$$V_{SENSE} = \frac{R_{DS_{SENSE}} \cdot I_{LOAD}}{K}$$

## 4.2 $R_{Sense}$ and voltage divider design

$R_{sense}$ and the voltage divider resistors (see R3-R4 and R7-R8 in *Figure 5*) must be selected considering the maximum output current[a] and the maximum $V_{Sense}$ levels.

Multsense1 and Multsense2 signals are measured by using an ADC and under any working condition, the ADC input stage must not be saturated.

The default configuration of the X-NUCLEO-IPS02A is assembled with these components:

- $R_{sense}$: 1 kΩ
- R3 = 56 kΩ
- R4 = 36 kΩ

The voltage divider ratio defined by the *Equation 5:* is “0.39”:

**Equation 5**

$$Voltage""Diver""Ratio = \frac{R_4}{R_3 + R_4}$$

The attenuation introduced by the voltage divider avoids the ADC input stage also when $V_{Sense}$= $V_{SenseMax}$.

To measure the load current reading the Multsense1 and Multsense2 voltage levels, the attenuation due to the voltage divider must be considered in the computation. In detail, the Multsense1 and Multsense2 voltage levels must be multiplied by a factor (1/VolatgeDivideRatio); in this specific situation, the multiplier factor is 2.55.

a. In the maximum current level, the overshoot and transition must be considered.

# 5 Board schematics

Figure 4. Board schematic (part 1)

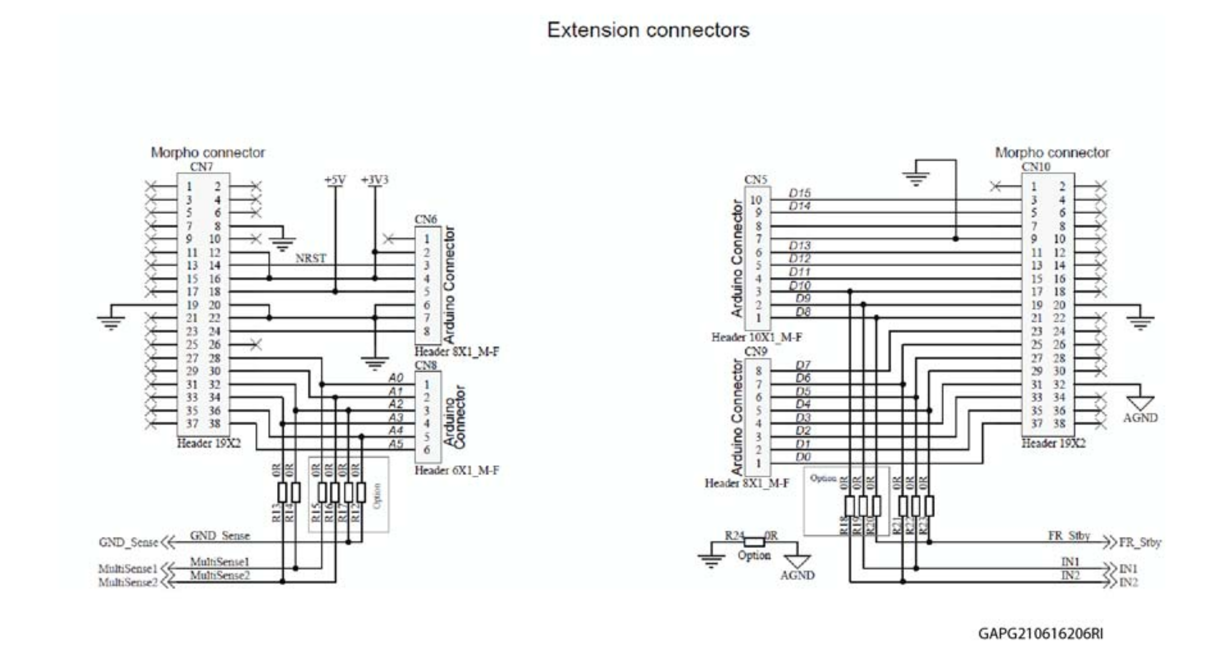
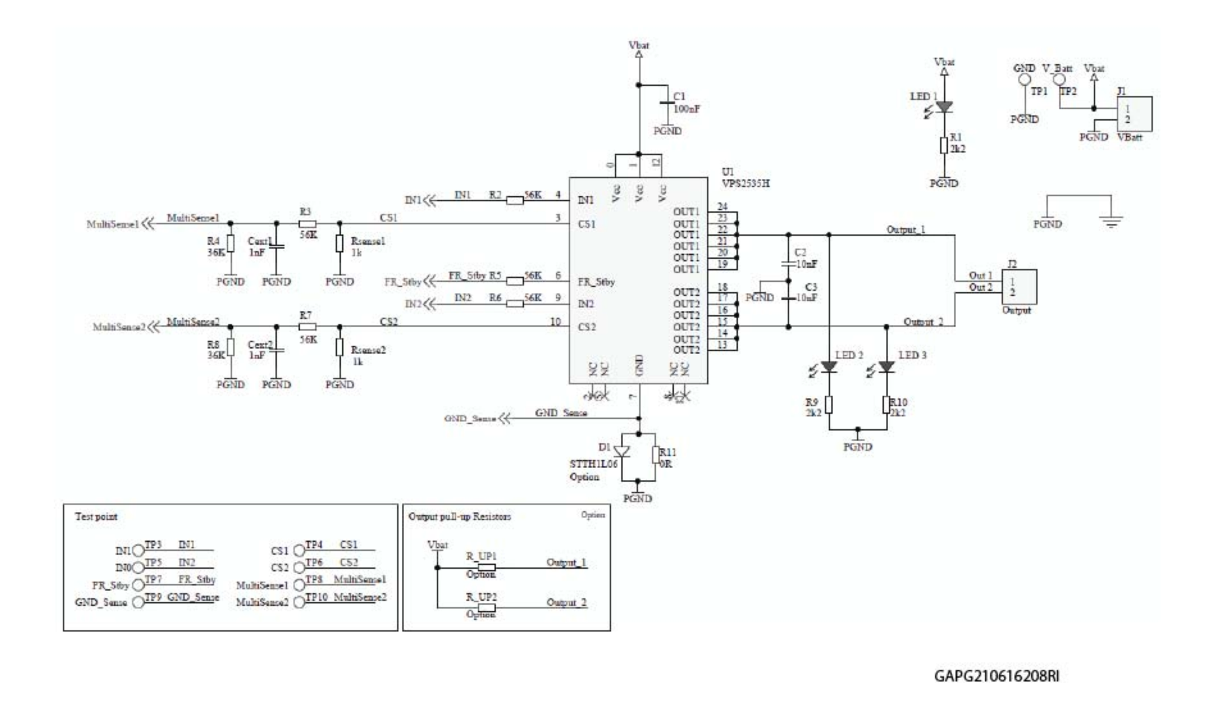



Figure 5. Board schematic (part 2)



# 6 PCB Layout

Figure 6. Top Layout

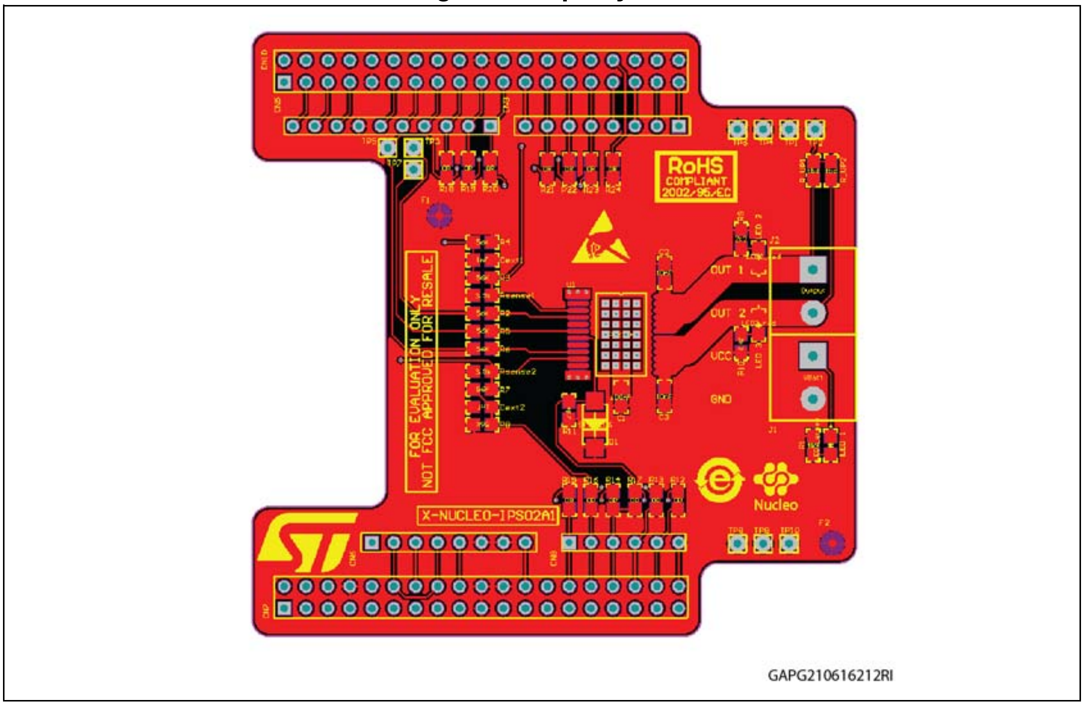
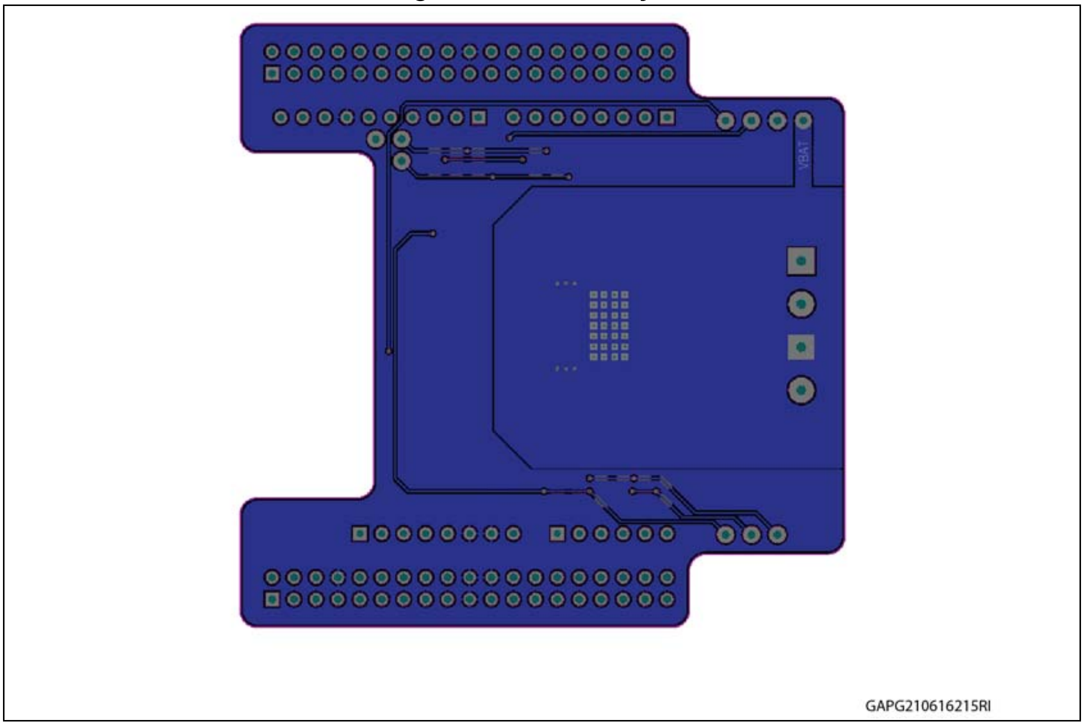



Figure 7. Bottom Layout



# 7 BOM

**Table 6. BOM List**

| Quantity | Comment | Designator | Footprint | Assembly Option |
|---|---|---|---|---|
| 1 | 100nF | C1 | 0805_C | |
| 2 | 10nF | C2, C3 | 0805_C | |
| 2 | 1nF | Cext1, Cext2 | 0805_C | |
| 1 | Header 10X1_M-F | CN5 | SIP10 Male-Female | |
| 2 | Header 8X1_M-F | CN6, CN9 | SIP8 Male-Female | |
| 2 | Header 19X2 | CN7, CN10 | SIP38 Female | |
| 1 | Header 6X1_M-F | CN8 | SIP6 Male-Female | |
| 1 | STTH1L06 | D1 | SMA | Not Assembled |
| 1 | VBatt | J1 | Terminal Block 2 POS | |
| 1 | Output | J2 | Terminal Block 2 POS | |
| 1 | LED2_green | LED 1 | 0805_LED | |
| 2 | LED2_red | LED 2, LED 3 | 0805_LED | |
| 3 | 2K2 | R1, R9, R10 | 0805_R | |
| 5 | 56K | R2, R3, R5, R6, R7 | 0805_R | |
| 2 | 36K | R4, R8 | 0805_R | |
| 6 | 0R | R11, R13, R14, R21, R22, R23 | 0805_R | |
| 7 | 0R | R12, R15, R17, R18, R19, R20, R24 | 0805_R | Not Assembled |
| 1 | 0R | R16 | 0805_R | Not Assembled |
| 2 | 1k | Rsense1, Rsense2 | 0805_R | |
| 2 | --- | R_UP1, R_UP2 | 0805_R | Not Assembled |
| 1 | GND | TP1 | TPoint | |
| 1 | V_Batt | TP2 | TPoint | |
| 1 | IN0 | TP3 | TPoint | |
| 1 | CS1 | TP4 | TPoint | |
| 1 | IN1 | TP5 | TPoint | |
| 1 | CS2 | TP6 | TPoint | |
| 1 | FR_Stby | TP7 | TPoint | |
| 1 | MultiSense1 | TP8 | TPoint | |
| 1 | GND_Sense | TP9 | TPoint | |

Table 6. BOM List (continued)

| Quantity | Comment | Designator | Footprint | Assembly Option |
|---|---|---|---|---|
| 1 | MultiSense2 | TP10 | TPoint | |
| 1 | VPS2535H | U1 | PSSO24 | |

# 8 Revision history

**Table 7. Document revision history**

| Date | Revision | Changes |
|---|---|---|
| 21-Jun-2016 | 1 | Initial release. |

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