

Getting started with the X-NUCLEO-DO40A1 industrial digital output expansion board for STM32 Nucleo

Introduction

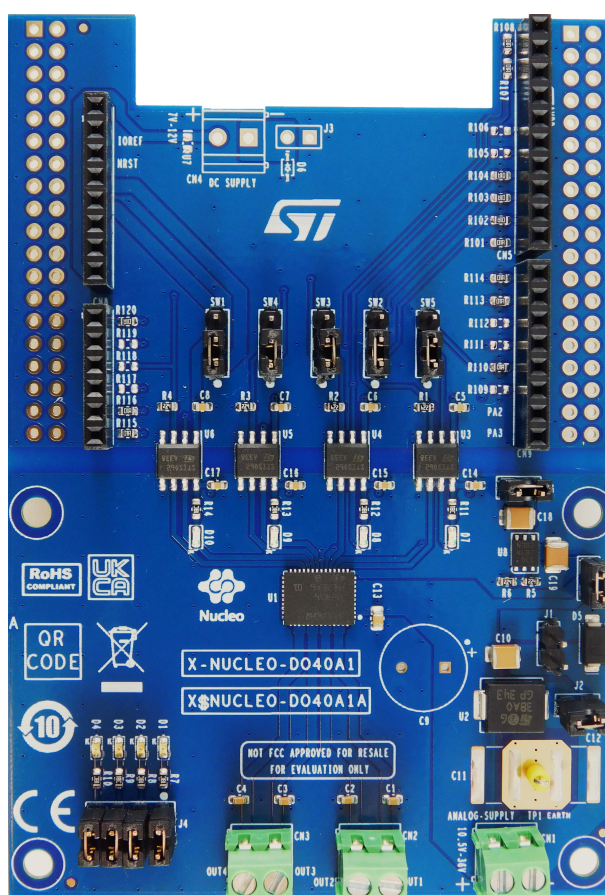
The **X-NUCLEO-DO40A1** is an industrial quad digital output expansion board for **STM32 Nucleo**. It provides a powerful and flexible environment for the evaluation of the driving and diagnostic capabilities of the **IPS4140HQ** quad high-side, smart power, solid-state relay in a digital output module connected industrial loads sinking ≤ 0.6 A.

The **X-NUCLEO-DO40A1** interfaces with the microcontroller on the **STM32 Nucleo** via **STIS0621** digital isolators. The galvanic isolation between the industrial field and Arduino® UNO R3 connectors is guaranteed up to 2.8 kVrms by the digital isolators.

The expansion board can be connected to either a **NUCLEO-F401RE** or a **NUCLEO-G431RB** development board.

You can also evaluate a system consisting of an **X-NUCLEO-DO40A1** expansion board stacked on other expansion board compatible in terms of logic signals assignments.

Figure 1. X-NUCLEO-DO40A1 expansion board



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1 Getting started

1.1 Overview

The **X-NUCLEO-DO40A1** embeds the **IPS4140HQ** quad high side intelligent power switch (IPS), which features overcurrent and overtemperature protections for safe control of ≤ 0.6 A industrial loads.

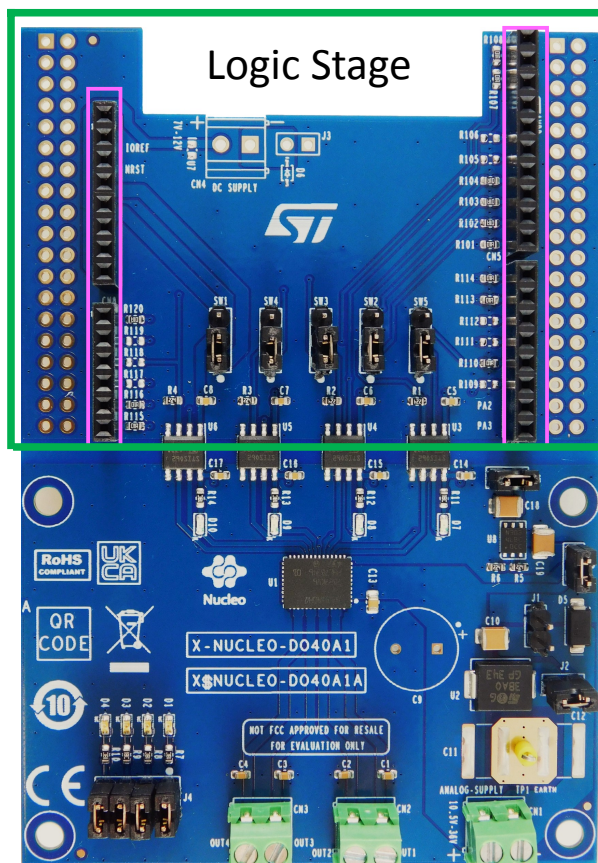
The board is designed to meet the application requirements for the galvanic isolation between the logic side (microcontroller signals side) and process side (industrial field / 24 V side): the isolation is implemented through four bidirectional digital isolators **STISO621** for IN_x driving signals and related $STATUS_x$ per-channel overtemperature diagnostic.

- Based on the **IPS4140HQ** quad high-side switch, which features:
 - Operating voltage range 10.5 to 36 V
 - Operating current range ≤ 0.6 A per channel
 - 3.3 V and 5 V compatible I/O
 - Low-power dissipation (Standby current = 250 μ A, $R_{ON(TYP)} = 80$ m Ω)
 - Can drive resistive, capacitive and inductive loads (with fast demagnetization)
 - Undervoltage shutdown with hysteresis
 - Per-channel open-drain thermal fault diagnostic pins
 - Per-channel overload, short circuit, and thermal junction protections
 - Thermal case protection
 - Not simultaneous channel reactivation at thermal case reset
 - Loss of GND protection
 - Designed to meet IEC61131-2, IEC 61000-4-2 (up to ± 25 kV), IEC61000-4-4, and IEC61000-4-5
 - QFN48L 8x6 mm package
- Process side operating range: 11 V or 36 V
- Process side reverse polarity protection (J1 open) by **STPS1H100A**
- Supply rail surge pulse protection (J2 closed) by **SMC30J30CA**
- On board high efficiency 24 V to 3.3 V LDO (**LDO40LPU33**)
- Green LEDs for outputs on/off status (J4 close 1-2, 3-4, 5-6, 7-8)
- Red LEDs for thermal faults (D7, D8, D9, D10) visualization
- Galvanic isolation between logic and process sides by **STISO621** digital isolators
- Logic side operating voltage 3.3 V (SW1 close 1-2) or 5 V (SW1 close 2-3)
- Logic side equipped with Arduino® UNO R3 connectors
- Digital signals driving output channels (default = CN5[1,2], CN9[7,8])
- Digital signals for thermal diagnostic (default = CN5[9,10] and CN8[5, 6])
- Easy digital signals reconfigurability by SW2, SW3, SW4, SW5
- Compatible with STM32 Nucleo development boards
- RoHS and China RoHS compliant
- CE certified

1.1.1 Digital section

The digital section is associated with the STM32 interface and the digital supply voltage to and from the X-NUCLEO-DO40A1 expansion board.

Figure 2. X-NUCLEO-DO40A1 expansion board: digital interface section



The solid green line indicates the whole digital interface section. The pink rectangles identify the Arduino® UNO R3 connectors.

The four Arduino® UNO R3 connectors:

- allow the expansion board to communicate with the **STM32 Nucleo** development board microcontroller accessing the STM32 peripheral and GPIO resources;
- provide the digital supply voltage between the **STM32 Nucleo** development board and the **X-NUCLEO-DO40A1** expansion board, in either direction.

Normally, the **STM32 Nucleo** development board supplies the expansion board by a 3v3 or 5v0 generated by the USB. You can select the preferred voltage on the expansion board via SW1 (3v3 closing pins 1-2; 5v0 closing pins 2-3).

Alternatively, it is possible to supply the **STM32 Nucleo** development board by the expansion board. In this case, an external supply voltage (7-12 V) should be connected to the CN4 connector (not mounted by default) on the expansion board and the ground loop should be closed by mounting D6 (enabling the reverse polarity protection) or by closing J3 (without reverse polarity).

To supply the VIN voltage rail, it is necessary:

- on the **NUCLEO-F401RE**, to close the JP5 jumper between pins 2 and 3 and open the JP1 jumper;
- on the **NUCLEO-G431RB**, to open the JP5 jumper between pins 1 and 2 and close the JP5 jumper between pins 3 and 4.

1.1.2 Power section

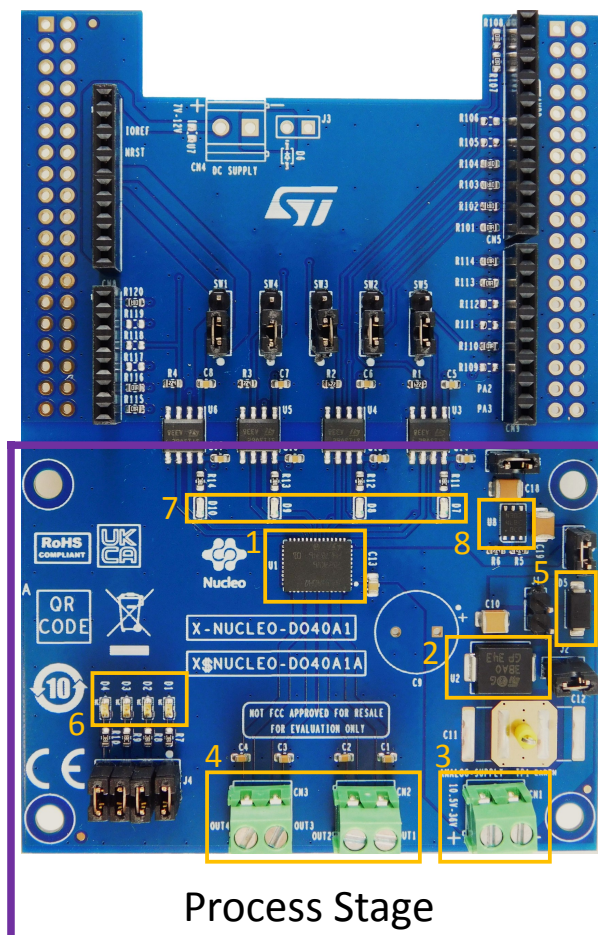
The **X-NUCLEO-DO40A1** offers four connections points for the loads through the connectors CN2 and CN3. The other sides of the load are connected to the reference/ground rail of the process stage.

The **X-NUCLEO-DO40A1** supplies the process stage by the VCC rail from CN1: the **IPS4140HQ** (U1) and **LDO40LPU33** (U8) are directly supplied by VCC rail; the **STISO621** is supplied from the VISO_P rail (= 3.3 V) provided at the output stage of **LDO40LPU33**.

Normally, the CN1 is connected to a typical 24 V industrial rail. The **X-NUCLEO-DO40A1** offers a basic reverse polarity protection on CN1 by the **STPS1H100A** (D2). If necessary, the reverse polarity protection can be bypassed by closing J1.

Figure 3. X-NUCLEO-DO40A1 expansion board: power section components

1. **IPS4140HQ**
2. Surge pulse suppressor
3. Power stage ground and 24 V rail connector
4. Load connectors
5. VCC rail reverse polarity protection
6. Output channels status green LEDs
7. Overtemperature diagnostic red LEDs
8. LDO (24 V to 3.3 V)



Process Stage

For EMC:

- the **SMC30J30CA** transient voltage suppressor (U2), enabled by closing J2, is placed between process stage supply rail and GND tracks to protect the **IPS4140HQ** against surge discharge on the supply rail path up to ± 500 V with $2\ \Omega$ coupling;
- in the common mode surge testing, two single-layer capacitors (C11 and C12 - not included) must be soldered at the predisposed locations;

- the [IPS4140HQ](#) output stages do not require additional EMC protections with respect to the IEC61000-4-2, IEC61000-4-3, IEC61000-4-4, IEC61000-4-5, IEC61000-4-8 standards

The EMC performances of the [X-NUCLEO-DO40A1](#) are detailed below:

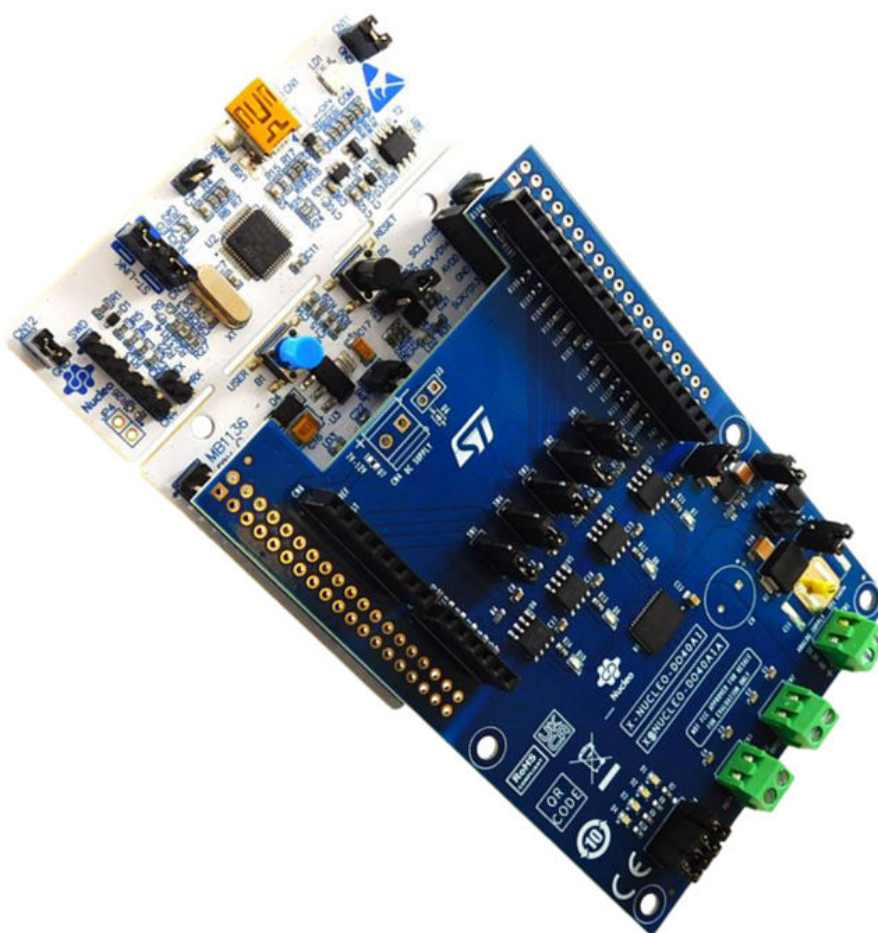
- for emission, compliance with standards:
 - EN IEC 61000-6-3:2021
 - EN 55032:2015 +A1:2020
- for immunity, compliance with standards:
 - EN IEC 61000-6-1:2019
 - EN 55035:2017 +A11:2020

1.2 Hardware requirements

The X-NUCLEO-DO40A1 expansion board is designed to be used with the NUCLEO-F401RE or NUCLEO-G431RB and STM32 Nucleo development boards.

To function correctly, the X-NUCLEO-DO40A1 must be plugged onto the matching Arduino® UNO R3 connector pins on the STM32 Nucleo board as shown below.

Figure 4. X-NUCLEO-DO40A1 and STM32 Nucleo stack



1.3 System requirements

To use the STM32 Nucleo development boards with the X-NUCLEO-DO40A1 expansion board, you need:

- a Windows PC/laptop (Windows 7 or above)
- a type A to mini-B USB cable to connect the STM32 Nucleo development board to the PC when using a NUCLEO-F401RE development board
- a type A to micro-B USB cable to connect the STM32 Nucleo development board to the PC when using a NUCLEO-G431RB development board
- the X-CUBE-IPS firmware and software package installed on your PC/laptop

1.4 Board setup

- Step 1.** Connect the mini-USB or micro-USB cable to your PC to use the [X-NUCLEO-DO40A1](#) with [NUCLEO-F401RE](#) or [NUCLEO-G431RB](#) development board respectively.
- Step 2.** Download the proper firmware (.bin) onto the [STM32 Nucleo](#) development board microcontroller through [STM32ST-LINK utility](#), [STM32CubeProgrammer](#), and according to your IDE environment, as detailed in the table below.

Table 1. Nucleo development boards binary files

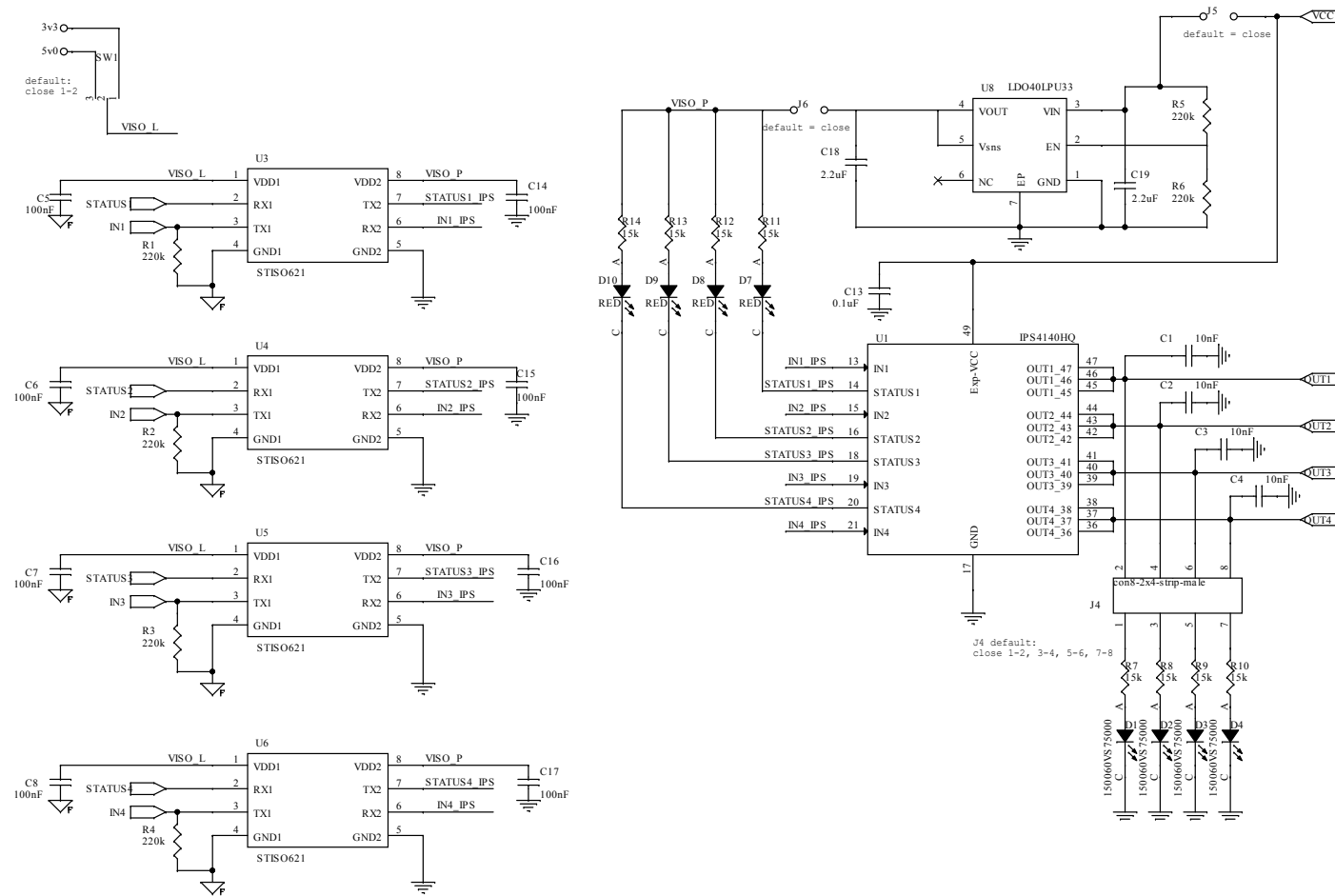
Nucleo board	Binary path
<i>NUCLEO-F401RE</i>	Projects\NUCLEO-F401RE\Examples\DO40A1\FourChannels\Binary\FourChannels.bin
<i>NUCLEO-G431RB</i>	Projects\NUCLEO-G431RB\Examples\DO40A1\FourChannels\Binary\FourChannels.bin

Note: Additional details are available inside the [X-CUBE-IPS](#) software package in each example project folder (*Examples\DO40A1\FourChannels\readme.html*)

- Step 3.** Connect the load on the output connectors (see [Section 1.1.2: Power section](#)).
- Step 4.** Provide the digital supply voltage (see [Section 1.1.1: Digital section](#)).
- Step 5.** Supply the [IPS4140HQ](#) device (see [Section 1.1.2: Power section](#)).
- Step 6.** Reset the example sequence using the black push button.
- Step 7.** Push the blue button on the [STM32 Nucleo](#) board to choose among the examples provided in the firmware package.

[illegible]

Figure 6. X-NUCLEO-DO40A1 circuit schematic (2 of 2)



3 Bill of materials

Table 2. X-NUCLEO-DO40A1 bill of materials

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
1	4	C1 C2 C3 C4	10nF, 0603 (1608 Metric), 50V, +/-10%	CAPACITOR CERAMIC SMD 0603	Würth Electronics Inc.	885012206089
2	8	C5 C6 C7 C8 C14 C15 C16 C17	100nF, 0603 (1608 Metric), 16V, +/-10%	CAPACITOR CERAMIC SMD 0603	Würth Electronics Inc.	885012206046
3	0	C9	47uF (N.M.), Radial, Can, 100V, +/-20%	CAP 47 uF 20% 100 V (not mounted)	Würth Electronics Inc.	860040875002
4	3	C10 C18 C19	2.2uF, 1210 (3225 Metric), 100V, +/-10%	CAP CER 2.2uF 100V X7R 1210	Würth Electronics Inc.	885012209071
5	0	C11 C12	4700pF, 1825 (4564 Metric), 3000V (3kV), +/-10%	CAP CER 4700PF 3KV X7R 1825 (not mounted)	Vishay Vitramon	HV1825Y472KXHATHV
6	1	C13	0.1uF, 0805 (2012 Metric), 100V, +/-10%	CAP CER 0.1uF 100V X7R 0805	Würth Electronics Inc.	885012207128
7	3	CN1 CN2 CN3	691214110002, 7.4X7 pitch 3.5	TERM BLK 2POS SIDE ENT 3.5MM PCB	Würth Electronics Inc.	691214110002
8	0	CN4	691214110002, 7.4X7 pitch 3.5	TERM BLK 2POS SIDE ENT 3.5MM PCB (not mounted)	Würth Electronics Inc.	691214110002
9	1	CN5	SSQ-110-04-F- S	CONN RCPT 10POS 0.1 GOLD PCB	Samtec Inc.	SSQ-110-04-F-S
10	2	CN6 CN9	SSQ-108-04-F- S	CONN RCPT 8POS 0.1 GOLD PCB	Samtec Inc.	SSQ-108-04-F-S
11	0	CN7 CN10	SSQ-119-04-L- D	CONN RCPT 38POS 0.1 GOLD PCB (not mounted)	Samtec Inc.	SSQ-119-04-L-D
12	1	CN8	SSQ-106-04-F- S	CONN RCPT 6POS 0.1 GOLD PCB	Samtec Inc.	SSQ-106-04-F-S
13	1	D5	STPS1H100A, DO-214AC, SMA, 1A	DIODE SCHOTTKY 100V 1A SMA	ST	STPS1H100A
14	0	D6	BAT48JFILM, SC-76, SOD-323, 750mV @ 200mA 350mA (DC)	DIODE SCHOTTKY 40V 350MA SOD323 (not mounted)	ST	BAT48JFILM
15	4	D1 D2 D3 D4	150060VS7500 0, 0603 (1608 Metric), 20mA	LED GREEN CLEAR 0603 SMD	Würth Electronics Inc.	150060VS75000

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
16	4	D7 D8 D9 D10	150060RS7500 0, 0603 (1608 Metric), 20mA	LED RED CLEAR 0603 SMD	Würth Electronics Inc.	150060RS75000
17	4	J1 J2 J5 J46	JUMPER-con2- strip-male	JUMPER- CONN HEADER .100 STR 2POS	Würth Electronics Inc.	61300211121
18	0	J3	JUMPER-con2- strip-male	JUMPER- CONN HEADER .100 STR 2POS	Würth Electronics Inc.	61300211121
19	1	J4	con8-2x4-strip- male	CONN HEADER .100 DUAL STR 8POS	Würth Electronics Inc.	61300821121
20	6	R1 R2 R3 R4 R5 R6	220k 0603 (1608 Metric) 0.1W, 1/10W 1%	CHIP RESISTOR SMD 1% 1/10W 0603	ANY	ANY
21	8	R7 R8 R9 R10 R11 R12 R13 R14	15k 0603 (1608 Metric) 0.1W, 1/10W 1%	CHIP RESISTOR SMD 1% 1/10W 0603	ANY	ANY
22	12	R101 R102 R103 R104 R107 R108 R110 R113 R114 R115 R116 R120	100, 0603 (1608 Metric), 0.1W, 1/10W, +/-1%	RES SMD 100 OHM 1% 1/10W 0603	ANY	ANY
23	0	R105 R106 R109 R111 R112 R117 R118 R119	100, 0603 (1608 Metric), 0.1W, 1/10W, +/-1%	RES SMD 100 OHM 1% 1/10W 0603	ANY	ANY
24	5	SW1 SW2 SW3 SW4 SW5	con3-strip-male	CONN HEADER VERT 3POS 2.54MM MALE	Würth Elektronik	61300311121
25	1	TP1	5001 0.100" Dia x 0.180" L (2.54mm x 4.57mm)	TEST POINT PC MINI .040"D BLACK	Keystone Electronics	5001
26	1	U1	IPS4140HQ QFN48L (8x6 mm)	QUAD HIGH- SIDE INTELLIGENT POWER	ST	IPS4140HQ
27	1	U2	SMC30J30CA, SMC, 3kW	TVS DIODE 33.3V 48.4V SMC	ST	SMC30J30CA
28	4	U3 U4 U5 U6	STISO621, 8- SOIC (0.268", 6.81mm Width)	Dual Channel Digital Isolator	ST	STISO621
29	0	U7	ESDA15P60-1U 1M, 2-UDFN	TVS DIODE 13.2V 22.7V 1610 (not mounted)	ST	ESDA15P60-1U1M
30	1	U8	LDO40LPU33	400 mA, 38 V low-dropout regulator	ST	LDO40L



Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
31	13	N/A	Shunt, 2.54mm	Close jumper	Würth Electronics Inc.	60900213421

4 Board versions

Table 3. X-NUCLEO-DO40A1 versions

PCB version	Schematic diagrams	Bill of materials
X\$NUCLEO-DO40A1A ⁽¹⁾	X\$NUCLEO-DO40A1A schematic diagrams	X\$NUCLEO-DO40A1A bill of materials

1. This code identifies the X-NUCLEO-DO40A1 evaluation board first version. It is printed on the board PCB.

5 Regulatory compliance information

Notice for US Federal Communication Commission (FCC)

For evaluation only; not FCC approved for resale

FCC NOTICE - This kit is designed to allow:

(1) Product developers to evaluate electronic components, circuitry, or software associated with the kit to determine

whether to incorporate such items in a finished product and

(2) Software developers to write software applications for use with the end product.

This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter 3.1.2.

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À des fins d'évaluation uniquement. Ce kit génère, utilise et peut émettre de l'énergie radiofréquence et n'a pas été testé pour sa conformité aux limites des appareils informatiques conformément aux règles d'Industrie Canada (IC).

Notice for the European Union

This device is in conformity with the essential requirements of the Directive 2014/30/EU (EMC) and of the Directive 2015/863/EU (RoHS). Compliance to EMC standards in Class A (industrial intended use).

Notice for the United Kingdom

This device is in compliance with the UK Electromagnetic Compatibility Regulations 2016 (UK S.I. 2016 No. 1091) and with the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2012 (UK S.I. 2012 No. 3032). Compliance to EMC standards in Class A (industrial intended use).

6 References

Freely available on www.st.com:

1. [IPS4140HQ datasheet](#)
2. [UM3035: "Getting started with X-CUBE-IPS industrial digital output software for STM32 Nucleo"](#)
3. [NUCLEO-F401RE documentation](#)
4. [NUCLEO-G431RB documentation](#)

Revision history

Table 4. Document revision history

Date	Revision	Changes
23-Sep-2024	1	Initial release.

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