AN5041

Application note

IO-Link solution based on STEVAL-IDP004V2 master evaluation board and STEVAL-IDP003V1 kit

Introduction

The solution is designed for IO-Link communication in factory automation systems.

The system lets you implement P2P communication based on a physical IO-Link layer, using the STEVAL-IDP004V2 as the master node and the STEVAL-IDP003V1 as the device node.

With these, you can address various scenarios:

- remote machine monitoring for predictive maintenance or diagnostics (vibration analysis or temperature evaluation close to machine bearings)
- environment monitoring (humidity check, temperature check, pressure check and so on)
- production line monitoring (object proximity, acceleration monitoring)

The IO-Link physical layer is implemented using the L6360 and L6362A ST IO-Link transceivers representing the master node IC and device node IC, respectively. Both of these are soldered on dedicated microcontroller boards, creating a network node.

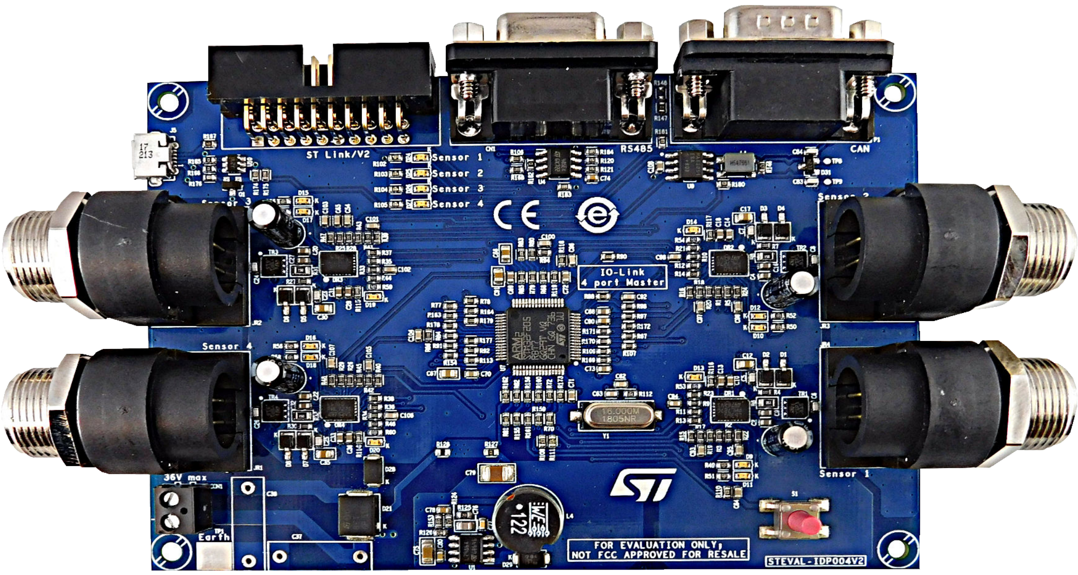
In this solution, the STEVAL-IDP004V2 represents an IO-Link master hub, capable of hosting up to four end nodes simultaneously. The end nodes are the industrial sensor evaluation boards here represented by the STEVAL-IDP003V1.

The physical connection between these two parts is achieved with industrial M12 connectors, with different pinouts for master and device network nodes, as established by the IO-Link standard. Electrical connection is implemented via a typical three pole cable, not shielded, with one wire used for communication and two wires for supply voltage.

Further flexibility is provided in the form of communication interfaces (RS-485, CAN and USB) on the STEVAL-IDP004V2 that can be used for data exchange with additional units (i.e., PLC or HMI), and with multiple sensor connections on the STEVAL-IDP003V1.

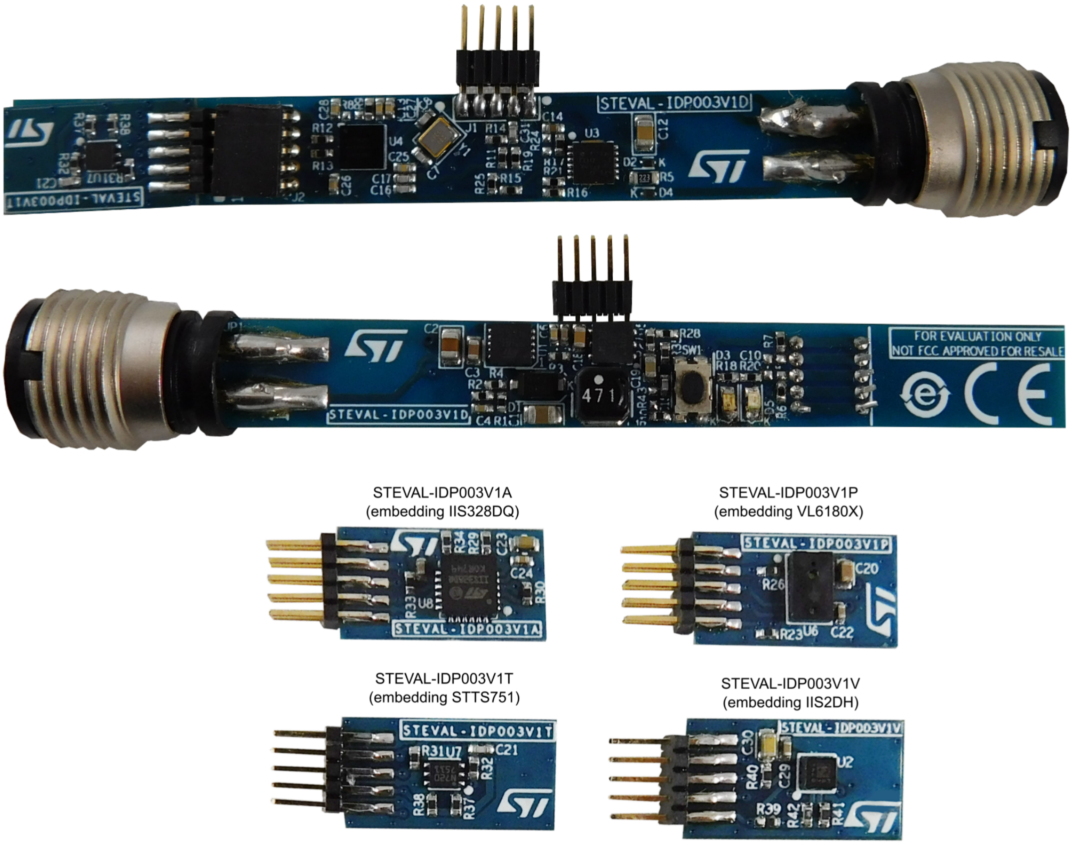
Note: *The STEVAL-IDP004V2 has the IO-Link stack embedded on the on-board STM32. The protocol stack is provided by TEConcept GmbH and comes with some limitations, as detailed further on. Be aware that the STSW-IO-LINK implements only the physical layer without stack. Programming it into the microcontroller you lose the full stack. This process is irreversible.*

Figure 1. STEVAL-IDP004V2 master evaluation board



Note: *The STEVAL-BFA001V2B is also supported as end node, using the IO-Link stack or the STSW-IO-LINK master firmware version. The master firmware allows data visualization and power spectrum plot on PC, using the graphical user interface available in the STSW-BFA001V2 software package.*

Figure 2. STEVAL-IDP003V1 kit



Note: All the topics described in this document are valid also for the STEVAL-IDP004V1 master evaluation board, except for the IO-Link stack section.

1 Hardware description

1.1 STEVAL-IDP004V2 master hub overview

The STEVAL-IDP004V2 is designed to represent a complete master unit with several communication interfaces like IO-Link, RS-485, CAN and USB.

L6360 transceivers have two different voltage reference: one on the V_{CC} pin with a 18 to 32V voltage range; the second one on the VH pin which can be supplied via a DC-DC converter in buck configuration or via the main V_{CC} supply.

The other interface are supplied as follows: RS-485 and CAN interfaces are supplied using the 3.3 V generated by the L6360 ICs, whereas the USB is supplied using the 5 V on the connector, since the peripheral works in slave mode and it is managed through a microcontroller interface based on the STM32F205RBT7 ARM® Cortex®-M3.

As this board is designed to work in industrial applications, extra care has been taken in layout routing and protections implemented to improve robustness in terms of EMC compliance.

Figure 3. STEVAL-IDP004V2 functional blocks

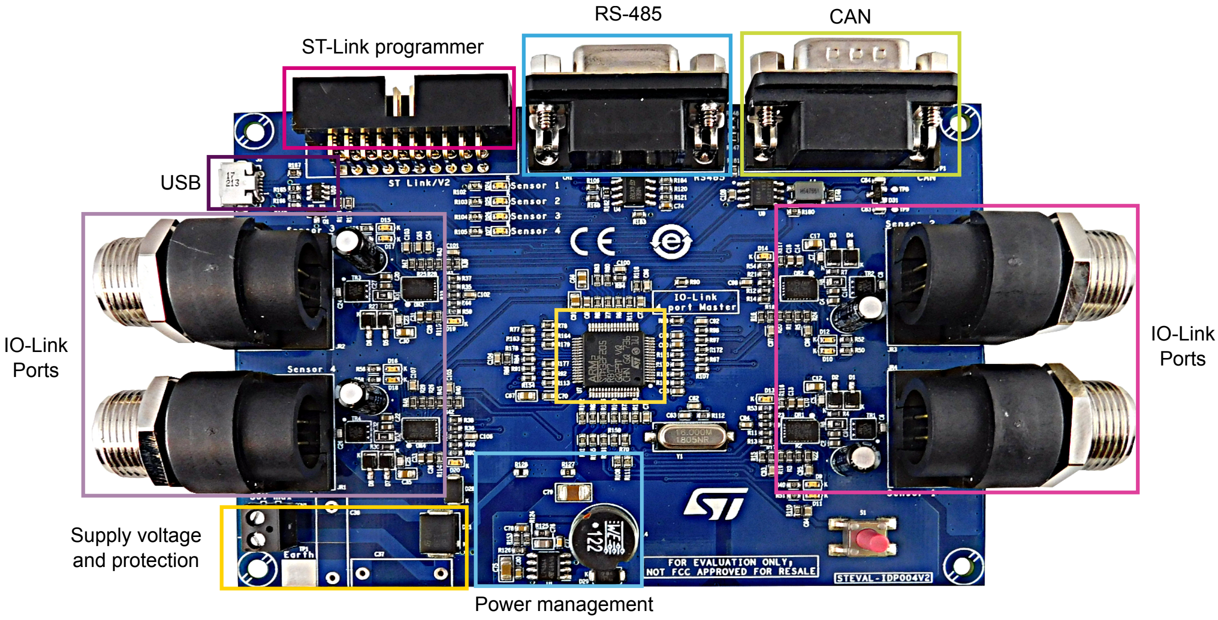
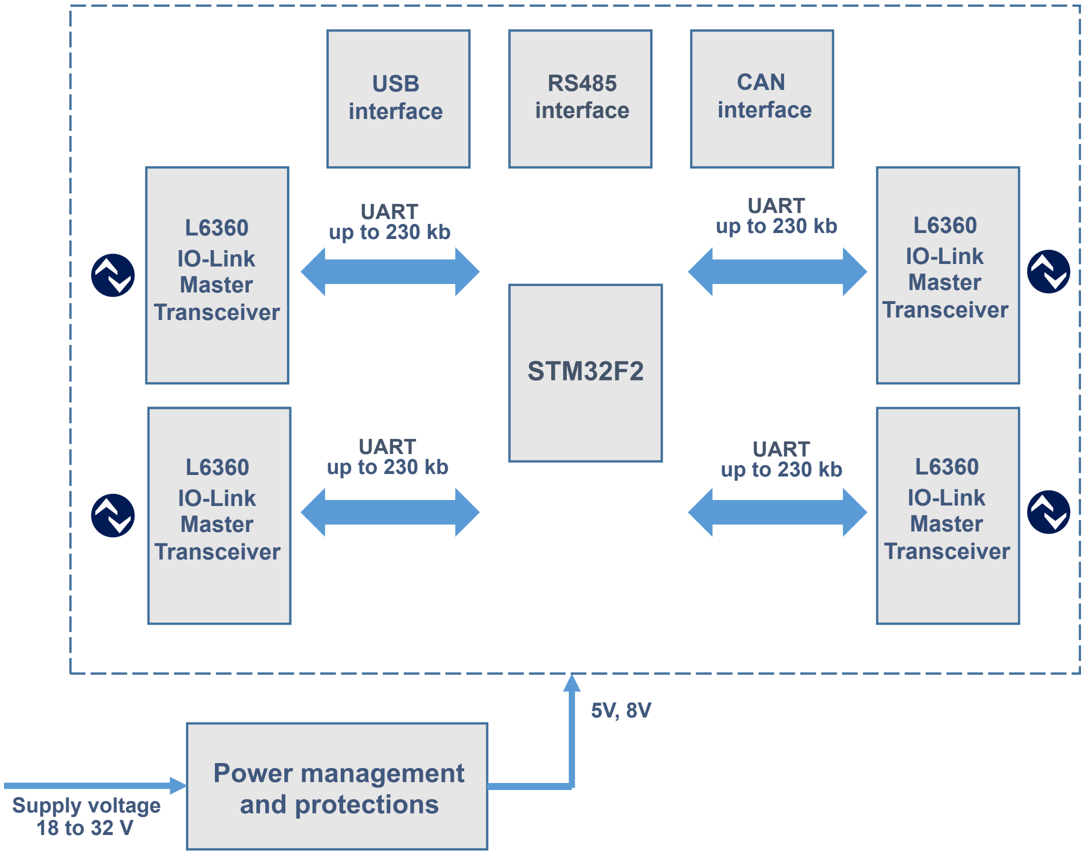


Figure 4. STEVAL-IDP004V2 block diagram



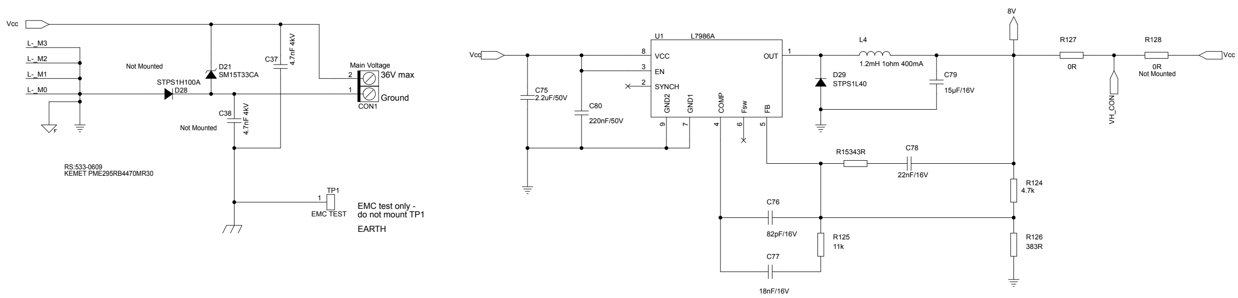
1.1.1 Power management and protection

The input stage is designed to adhere to the 18 to 32 V voltage range required by the standard.

The supply voltage is provided to the board via screw connector CON1 and stepped-down by the DC-DC converter to a lower voltage reference. The switching converters is the L7986A switching regulator IC, used to scale the main supply voltage to 8 V with a current capability of 400 mA (voltage reference used for VH input pin of L6360).

Furthermore, to improve the robustness on the supply line, the SM15T33CA Transil offers surge protection and the STPS1H100A power Schottky rectifier provides reverse polarity protection.

Figure 5. STEVAL-IDP004V2 power management schematic

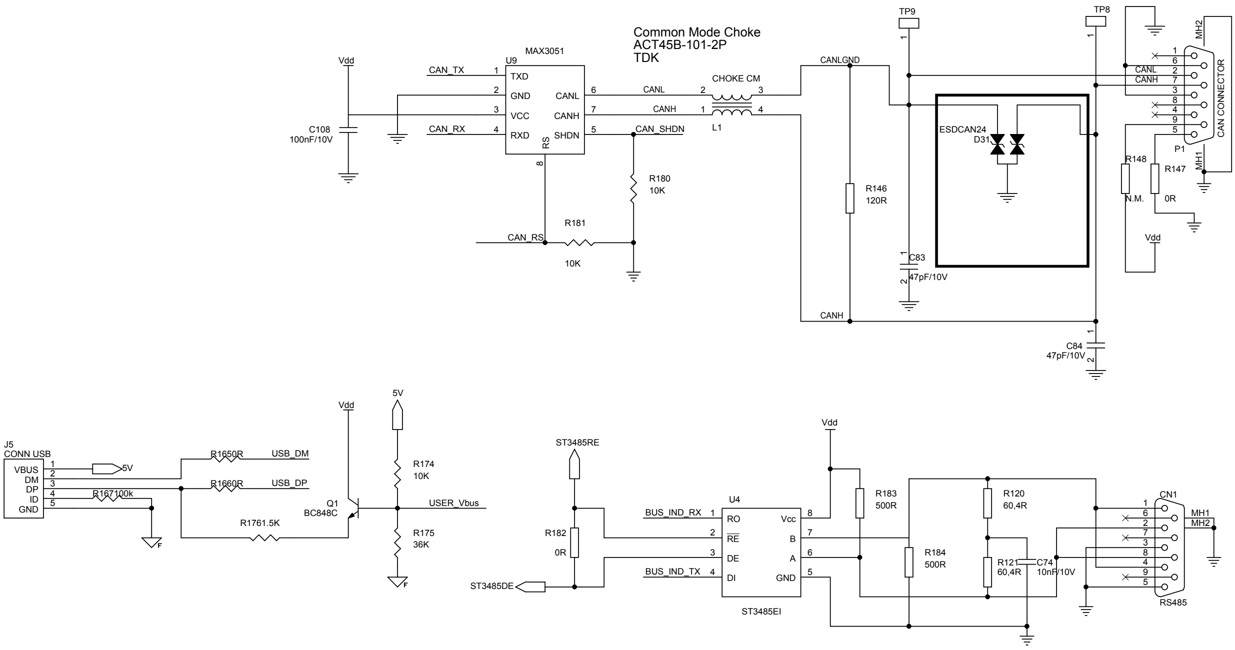


1.1.2 RS-485, USB and CAN interface

Several on-board interface modules can be used to interface with a PC or other control units. The PC interface is realized via the USB and RS-485 communication protocols: the USB and the RS-485 are used to handle a dedicated set of commands via PC to manage IO-Link IC configuration and remote sensor monitoring through the IO-Link physical layer.

The interface with the other communication bus is implemented using the CAN transceiver.

Figure 6. **RS-485, USB and CAN interface**



1.1.3 Master IO-Link ports

The IO-Link interface consists of four L6360 master ICs, each of them protected against surge discharge with ST Transil SPT01-335DEE and interfaced on the IO-Link bus through a 5-pin M12 female connector, as required by the standard.

1.1.3.1 IO-Link transceiver IC description

The L6360 programmable transceiver features:

1. integrated I²C serial peripheral and register for IC configuration
2. output stage to support IO-Link protocol timing, designed with several integrated protections against failure events (short-circuit, overtemperature)
3. output power stage with 500 mA maximum current capability, to power the slave node
4. two receiver input stages:
   - one connected to an IO-Link bus through an M12 connector
   - one available for other IO-Link bus connections
5. digital input pin ENL+ to handle L+ output power stage activation to provide supply voltage to slave node, device reset pin to reset the IC to default configuration, ENCQ digital pin to enable the IC in receiver or transmitter mode, and an IRQ latched interrupt pin
6. other digital input/output pins to manage I²C and IO-Link communication

This transceiver has embedded registers to configure different IC settings:

- output stage configurability (Push-Pull, High-Side, Low-Side)
- output current limitation threshold protection and delay protection activation on IO-Link line
- pull-down current generator on IO-Link line
- de-bounce time in receive mode according to communication speed
- LED registers to signal malfunction, communication status and IC status through different programming settings

The configuration is performed with the integrated I²C peripheral, according to the write operating mode provided in the **I²C protocol** section in the datasheet.

1. The configuration example sets the output stage in the **Configuration** register to push-pull configuration
2. Set the cut-off protection threshold in the **Control1** register to 580 mA
3. Set the cut-off delay time in the **Control1** register to 250 µs
4. Set de-bounce time in the **Control1** register to the communication speed

Following configuration, the ENCQ pin must be driven to enable communication transmission and reception. To enable transmission, the pin must be set to the high level, while to enable the receiver, the pin is set to the low level.

Once the transmitter or receiver stages are enabled, communication between master and device node can be managed by driving the UART inputs pin (INCQ and OUTCQ).

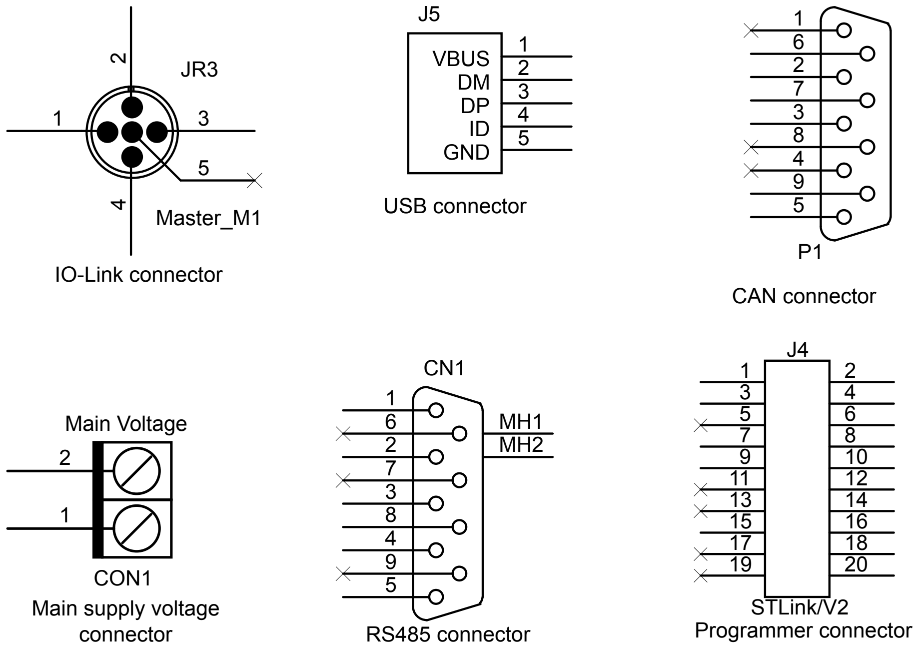
If some fault condition is detected during communication, the IRQ pin is activated.

1.1.4 Connectors

Table 1. Connectors

Part value	Part description	Pin	Name	Description
CON1	Main supply voltage	1	Negative pole	Ground supply voltage
		2	Positive pole	Supply voltage
J4	ST-Link Programmer	1, 2	V_{DD}	Ground Serial Data Reset
		3, 4, 6, 8, 10, 12, 14, 16, 18, 20	GND	Ground
		5, 11, 13, 17, 19	NC	Not connected
		7	SWDIO	Serial data
		9	SWCLK	Serial clock
		15	NRST	Reset
J5	USB connector	1	5V	Input supply
		2	DM	USB DM
		3	DP	USB DP
		4	ID	Pull down connected
		5	GND	Ground
CN1	DB9 RS-485 connector	1, 4	B	RS-485 inverted signal
		2, 8	A	RS-485 not inverted signal
		3, 5	GND	Ground
		6, 7, 9	NC	Not connected
CN2	DB9 CAN connector	1, 4, 8	NC	Not connected
		2	CANL	CAN bus line low
		3, 6	GND	Ground
		7	CANH	CAN bus line high
		9	V_{DD}	Voltage reference N.C
JR1, JR2, J3, J4	M12 IO-Link connector	1	L+	Device board supply
		2	IQ	Second bus line
		3	L-	Device board ground
		4	CQ	IO-Link bus line
		5	NC	Not connected

Figure 7. STEVAL-IDP004V2 connector drawings



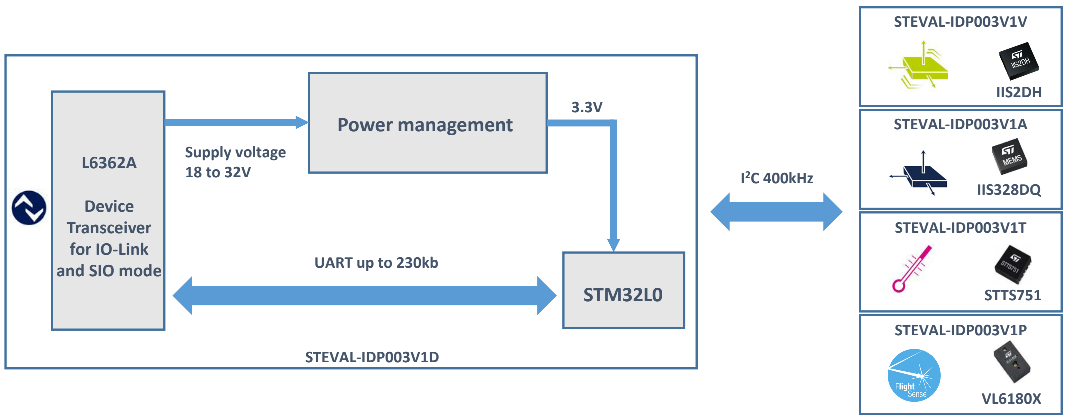
1.2 STEVAL-IDP003V1 kit overview

The STEVAL-IDP003V1 kit consists of:

1. STEVAL-IDP003V1D device board based on L6362A IO-Link PHY with small form factor for easy insertion in the M12 connector
2. STEVAL-IDP003V1A sensor board based on accelerometer MEMS sensor IIS328DQ
3. STEVAL-IDP003V1V sensor board based on accelerometer MEMS sensor IIS2DH
4. STEVAL-IDP003V1T sensor board based on temperature sensor STTS751
5. STEVAL-IDP003V1P sensor board based on proximity sensor VL6180X

The device boards and sensor boards are equipped with a small 1.27 mm pitch connector to reduce PCB area.

Figure 8. STEVAL-IDP003V1 block diagram



1.2.1 STEVAL-IDP003V1D evaluation board

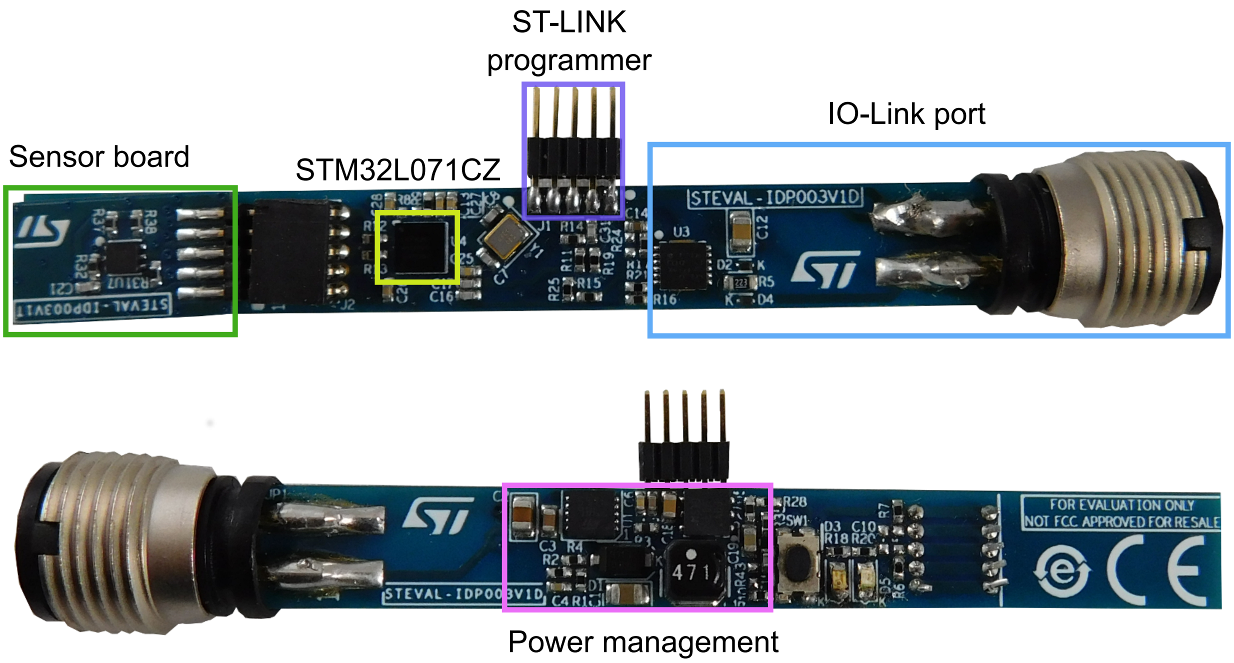
This board contains an L6362A IO-Link device transceiver to interface the sensors on the bus. It also implements power stage circuitry to generate 3.3 V voltage reference for microcontroller and sensors, using a DC-DC converter in buck configuration and a low drop voltage regulator.

The communication on the IO-Link bus and the communication with sensors are handled by the STM32L071CZY microcontroller via the USART and I²C peripherals, respectively.

The board features:

1. layout routing to improve robustness against EMC stress and minimize board size
2. connection on IO-Link bus in compliance with standard requirements in terms of connector pinout for device board
3. connection with sensor board using small 1.27 mm pitch connector for improved interfacing flexibility with different sensors.

Figure 9. STEVAL- IDP003V1D main components



1.2.2 Power management

The IO-Link specification requires that the sensor unit either be supplied directly on sensor side by battery or via the master node using the L+ line from the master IC.

The STEVAL-IDP003V1D is supplied by the master IO-Link node through the L+ line. Therefore, to obtain a lower reference voltage for the microcontroller, LED and sensors, the power management system has been designed to reduce the 18 to 32 V main supply voltage reference required by the standard down to 3.3 V.

The reduction is achieved using an L7986 DC-DC converter (to reduce the main down to 8 V) with an LDFPUR low drop voltage regulator in series (to reduce the 8 V down to 3.3 V). The 3.3 V (3v3-Ext voltage reference) voltage reference is used for on-board LED signaling and when it is needed, in place of the default microcontroller and sensor supply voltage provided by the L6362A internal voltage regulator.

To replace the voltage supply provided by the L6362A, resistor R43 must be replaced by the series R35 (0R) and R25 (100 kΩ resistor)

Figure 10. STEVAL-IDP003V1D power management schematic (1 of 3) - DC-DC converter

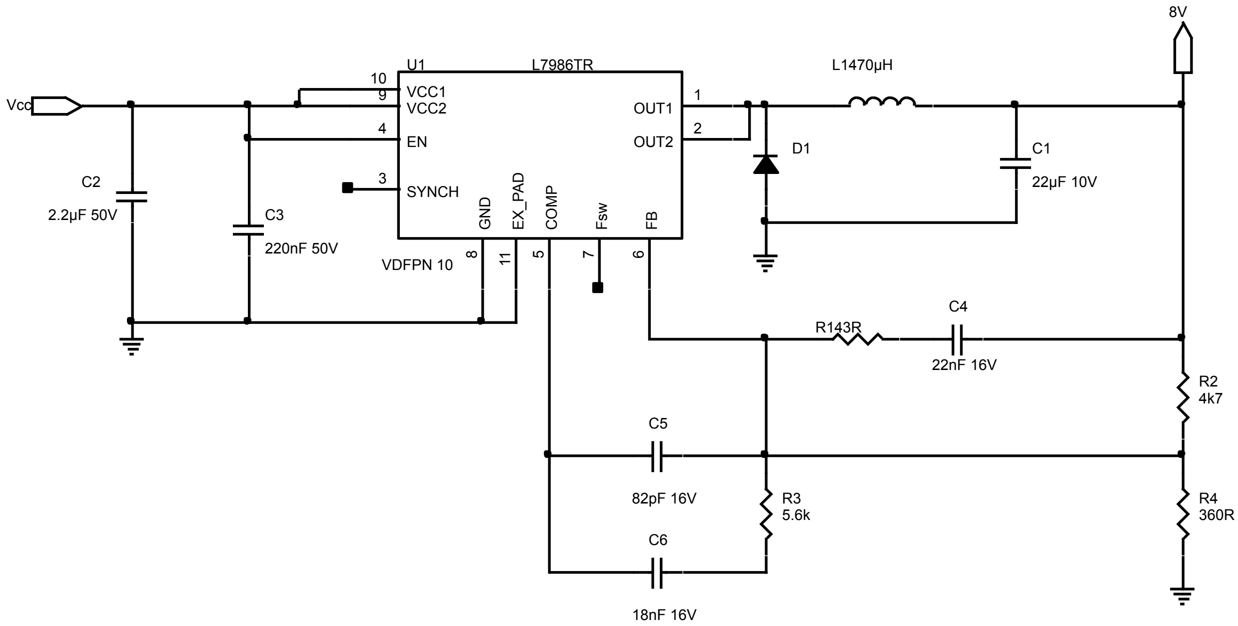


Figure 11. STEVAL-IDP003V1D power management schematic (2 of 3) - linear regulator

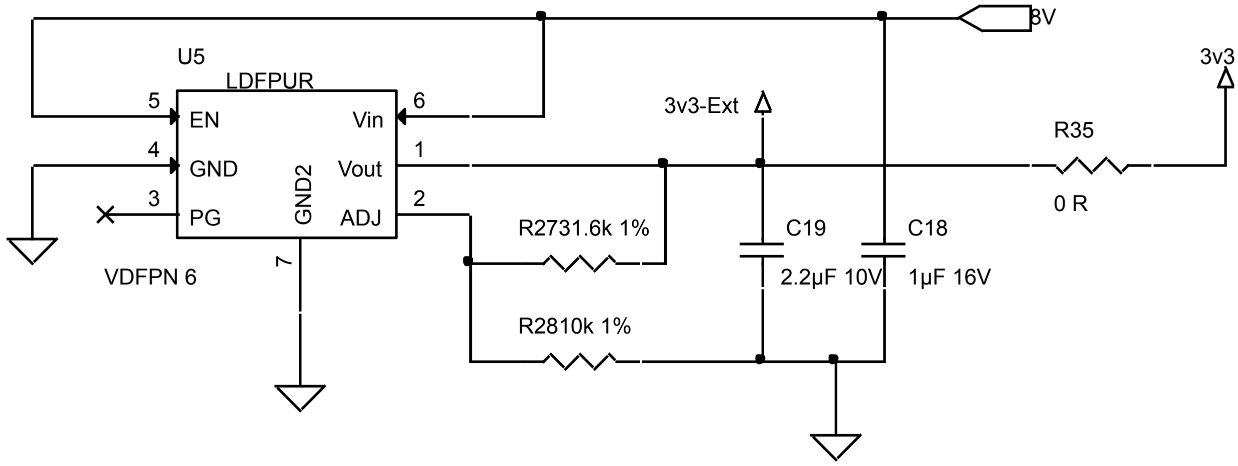
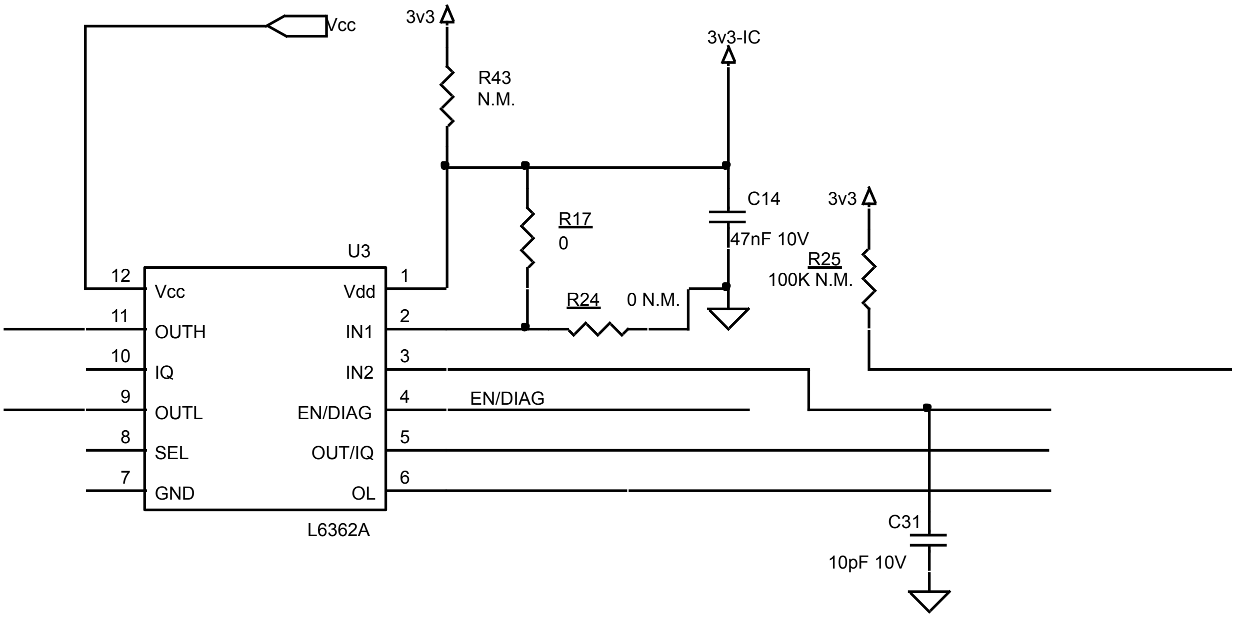


Figure 12. STEVAL-IDP003V1D power management schematic (3 of 3) - IO-Link transceiver



1.2.3 Device IO-Link port

The IO-Link interface consists of an L6362A IC connected to the IO-Link bus using the M12 4-pole male connector, as required by the standard.

1.2.4 IO-Link transceiver description

The programmable transceiver features:
1. configurable output stage (Push-Pull, High-Side, Low-Side)
2. configurable output voltage regulator
3. wake-up request detection
4. integrated protection like short-circuit, overtemperature
5. digital input/output ENDIAG pin to signal fault events
6. overload signaling

The output stage configuration and output voltage reference can be managed by hardware or firmware by simply configuring a fixed digital value on the IN1, IN2 and SEL pins. This setting modify the output stage configuration driving (Push-Pull, High-Side, Low-Side), IO-Link bus signal polarity (signal Inverted or not) managing the IN1 and IN2 pin and the output voltage reference provided on V_{DD} pin managing the SEL pin to suit application requirements.

On the STEVAL-IDP003V1, the IC bus interface is configured to have:
1. power stage in output push-pull
2. output signal polarity on IO-Link bus inverted
3. SEL pin to GND to provide 3.3 voltage reference
4. ENDIAG pin connected to pull-up
5. OL pin connected to pull-up

Once the IC is configured, data exchange with the master unit is a matter of managing serial communication via pin IN2 for transmission and pin OUTI/Q for reception. If a fault condition is detected during communication, the ENDIAG pin and/or the OL pin is activated and an interrupt is generated.

1.2.5 Sensor boards

The STEVAL-IDP003V1D can be interfaced with different sensors through a small 1.27 mm pitch connector. These small sensor boards host different kinds of sensors:

- IIS328DQ accelerometer MEMS sensor (STEVAL-IDP003V1A)
- VL6180X ToF proximity sensor (STEVAL-IDP003V1P)
- STTS751 temperature sensor (STEVAL-IDP003V1T)
- IIS2DH vibration MEMS sensor (STEVAL-IDP003V1V)

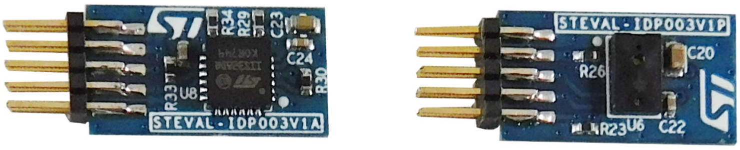
All of the above sensors exchange data with the sensor node via the I²C peripheral.

Also in this case, the layout routing is optimized to meet EMC testing requirements.

Figure 13. Sensor daughter boards

STEVAL-IDP003V1A
(embedding IIS328DQ)

STEVAL-IDP003V1P
(embedding VL6180X)



STEVAL-IDP003V1T
(embedding STTS751)

STEVAL-IDP003V1V
(embedding IIS2DH)

1.2.5.1 Sensor description

VL6180X (on the STEVAL-IDP003V1P) :

The VL6180X is the latest product based on ST's patented FlightSense™ technology. This is a ground-breaking technology allowing absolute distance to be measured independent of target reflectance. Instead of estimating the distance by measuring the amount of light reflected back from the object (which is significantly influenced by color and surface), the VL6180X precisely measures the time the light takes to travel to the nearest object and reflect back to the sensor (Time-of-Flight). Combining an IR emitter, a range sensor and an ambient light sensor in a three-in-one ready-to-use reflowable package, the VL6180X is easy to integrate and saves the end-product maker long and costly optical and mechanical design optimizations. The module is designed for low power operation. Ranging and ALS measurements can be automatically performed at user defined intervals. Multiple threshold and interrupt schemes are supported to minimize host operations. Host control and result reading is performed using an I²C interface. Optional additional functions, such as measurement ready and threshold interrupts, are provided by two programmable GPIO pins.

STTS751 (on the STEVAL-IDP003V1T)**:**

The STTS751 is a digital temperature sensor which communicates over a 2-wire SMBus 2.0 compatible bus. The temperature is measured with a user-configurable resolution between 9 and 12 bits. At 9 bits, the smallest step size is 0.5 °C, while at 12 bits, it is 0.0625 °C. At the default resolution (10 bits, 0.25 °C/LSB), the conversion time is nominally 21 milliseconds. The open-drain EVENT output is used to indicate an alarm condition in which the measured temperature has exceeded the user-programmed high limit or fallen below the low limit.

When the EVENT pin is asserted, the host can respond using the SMBus Alert Response Address (ARA) protocol to which the STTS751 will respond by sending its slave address. The STTS751 is a 6-pin device that supports user-configurable slave addresses. Via the pull-up resistor on the Addr/Therm pin, one of four different slave addresses can be specified. Two order numbers (STTS751-0 and STTS751-1) provide two different sets of slave addresses bringing the total available to eight. Thus, up to eight devices can share the same 2-wire SMBus without ambiguity, thereby allowing monitoring of multiple temperature zones in an application.

IIS2DH (on the STEVAL-IDP003V1V)**:**

The IIS2DH is an ultra-low-power high performance three-axis linear accelerometer with digital I2C/SPI serial interface standard output. The IIS2DH has user-selectable full scales of 2*g*/±4*g*/±8*g*/±16*g* and is capable of measuring accelerations with output data rates from 1 Hz to 5.3 kHz. The device may be configured to generate interrupt signals by two independent inertial wake-up/free-fall events as well as by the position of the device itself. The self-test capability allows the user to check the functionality of the sensor in the final application.

IIS328DQ (on the STEVAL-IDP003V1A) :

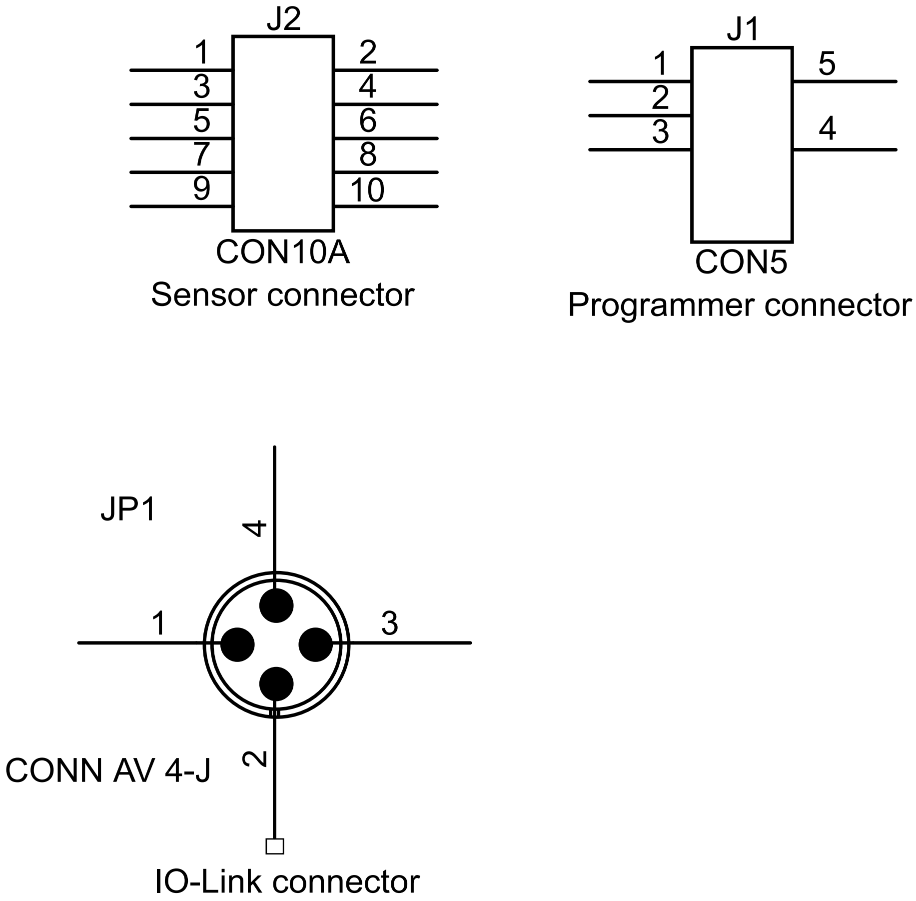
The IIS328DQ is an ultra-low-power high performance 3-axis linear accelerometer with a digital serial interface, SPI or I²C compatible. Recommended for industrial applications requiring an extended temperature range and long lifespan, the device features ultra-low-power operational modes that allow advanced power saving and smart sleep-to-wakeup functions. The IIS328DQ has dynamic user-selectable full-scales of ±2g/±4g/±8g and is capable of measuring accelerations with output data rates from 0.5 Hz to 1 kHz. The self-test capability allows the user to check the functioning of the sensor in the final application. The device may be configured to generate an interrupt signal through inertial wakeup events, or by the position of the device itself. Interrupt generators are programmable by the end user on-the-fly.

1.2.6 Connectors

Table 2. Connector details

Part value	Part description	PIN	Pin name	Pin description
JP1	IO-Link Connector	1	V_{CC}	Supply voltage
		2	NC	Not connected
		3	GND	Ground
		4	OUTH/OUTL	IO-Link Bus
J2	Sensor Connector	1, 2	GND	Ground
		3, 4	3v3	Supply voltage
		5, 6	I2C_SCL	I2C clock
		7, 8	I2C_SDA	I2C data
		9, 10	Interrupt	Sensor interrupt
J1	Programmer connector	1	3v3	Supply voltage
		2	GND	Ground
		3	SWDIO	SW data
		4	SWCLK	SW clock
		5	NRST	Reset

Figure 14. STEVAL-IDP003V1D connector drawings



2 EMC test

This IO-Link system has been built following the requirements coming from the factory automation, some tests have been performed to verify the robustness against stress events occurring during its normal life cycle.

Tests for electromagnetic compatibility as per IEC61000-4-2/4 and EN60947-5-2 are performed with respect to:

- IEC61000-4-2 ESD robustness
- IEC61000-4-4 Burst robustness
- EN60947-5-2 Surge robustness

Power is supplied through the L+ line on the STEVAL-IDP004V2 and the microcontroller on the STEVAL-IDP003V1D is set to perform continuous sensor data sampling.

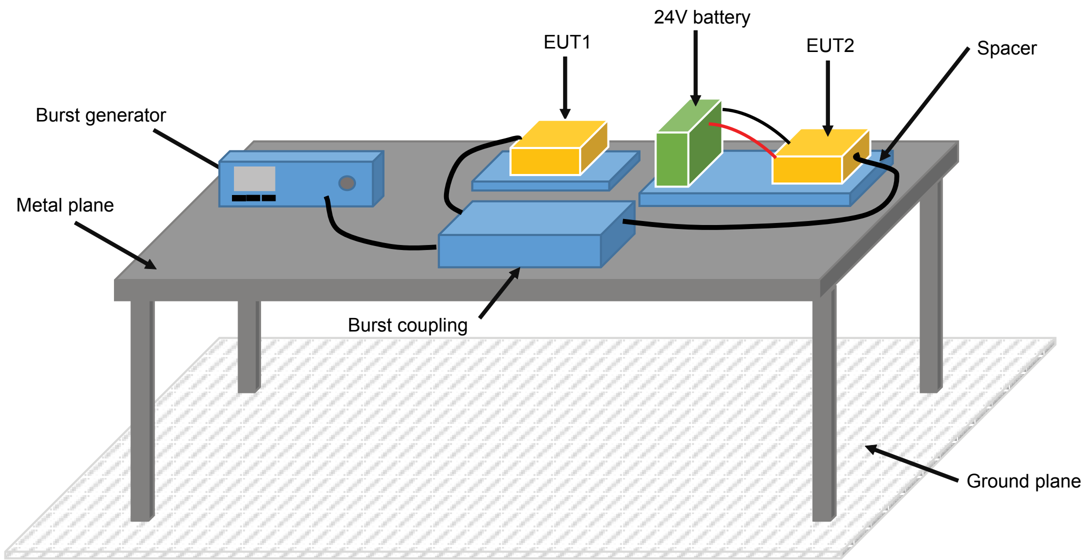
After testing, system functionality is verified through a complete STEVAL-IDP004V2 and STEVAL-IDP003V1 parameter request routine.

2.1 Burst test

Test setup:

- Burst Generator: UCS 500 N
- Coupling: 150 pF
- Spacer: 100 mm
- Supply voltage: 2x 12 V lead battery decoupled with 1mH inductor
- EUT1: STEVAL-IDP003V1
- EUT2: STEVAL-IDP004V2

Figure 15. **Burst test setup**



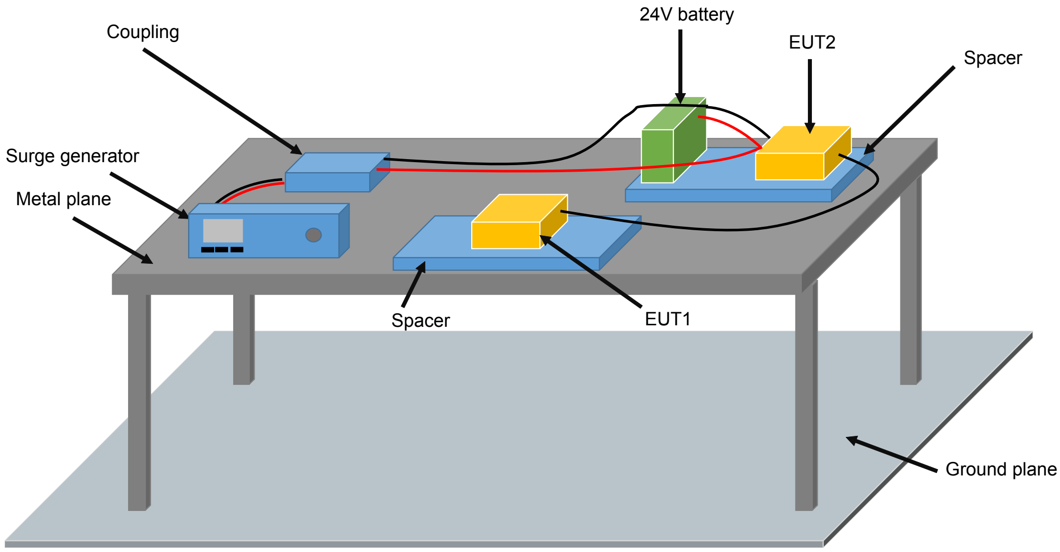
Test results: test successfully performed at ± 4 kV with criteria B.

2.2 Surge test in differential mode

Test setup:

- Surge generator: UCS 500N
- Coupling: 500 Ω + 18 µF
- Spacer: 100 mmS
- Supply voltage: 2x 12 V lead battery decoupled with 1 mH inductor
- EUT1: STEVAL-IDP003V1
- EUT2: STEVAL-IDP004V2

Figure 16. **Surge test setup**



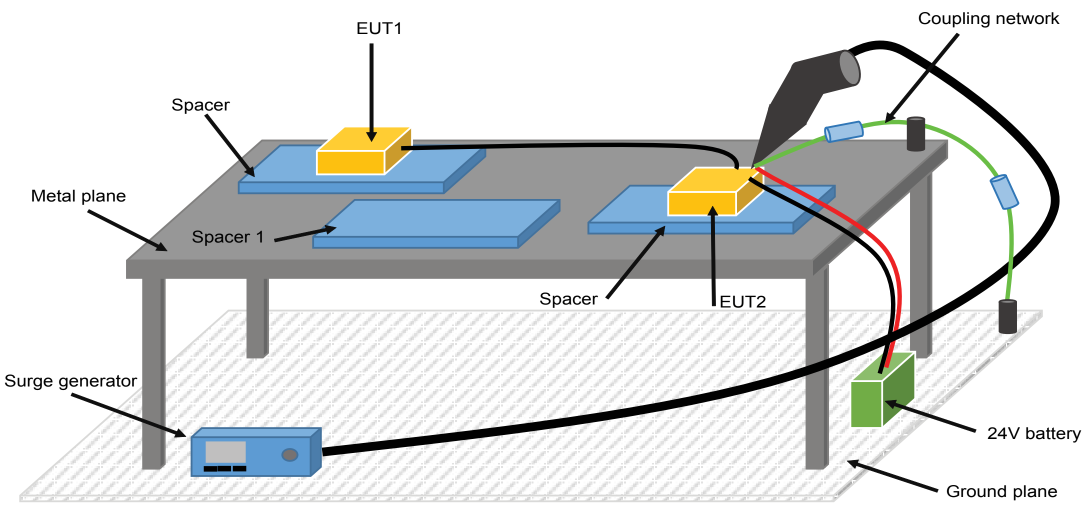
Test results: test successfully performed at ± 1.2 kV with criteria A.

2.3 ESD test in contact discharge

Test setup:

- ESD Generator: ESD 30N
- Coupling: 330 Ω + 150 pF
- Spacer: 100 mm
- Spacer 1: 30 mm
- Supply voltage: 2x 12 V lead battery decoupled with 1 mH inductor
- EUT1: STEVAL-IDP003V1
- EUT2: STEVAL-IDP004V2

Figure 17. **ESD test setup**



Test results: test successfully performed at ± 4 kV with criteria B.

3 Firmware description

The IO-Link evaluation kit is supported by two different firmware packages.

Both packages are useful to handle STEVAL-IDP004V2 to STEVAL-IDP003V1 communication and PC interface.

The first firmware package (STSW-IO-LINK) is based on a customized protocol developed by STMicroelectronics, whereas the second one is based on IO-Link stack plus a dedicated protocol for PC interface, both developed by TEConcept GmbH.

3.1 STSW-IO-LINK firmware package description

This solution consists of a complete firmware package released for the STEVAL-IDP003V1 and the STEVAL-IDP004V2 master board to facilitate system configuration as well as system data exchange and processing. It is based on the STM32Cube HAL library and was developed with the STM32CubeMX tool to help configure the microcontroller in each part and update the created workspace without any data loss.

The firmware includes the following functional blocks:

1. PC and system configuration with the RS-485 interface
2. Master-device communication using a customized protocol to exchange data between STEVAL-IDP004V2 and STEVAL-IDP003V1
3. Sensor data management to exchange data with sensors (STEVAL-IDP003V1T, STEVAL-IDP003V1V, STEVAL-IDP003V1A, STEVAL-IDP003V1P) and process it on the device board (STEVAL-IDP003V1D), in particular for vibration monitoring based on IIS2DH accelerometer MEMS sensor.

The first two points have been implemented with simple command declarations that allow configuration (e.g., STEVAL-IDP004V2 L6360 configuration) and data exchange between the master (STEVAL-IDP004V2) and device (STEVAL-IDP003V1) nodes.

The third point involves data acquisition routines running on the STEVAL-IDP003V1D board through I²C interface and subsequent processing. For vibration monitoring, dedicated routines for data processing using the DSP_Lib to perform FFT calculation have been implemented to calculate the vibration power spectrum.

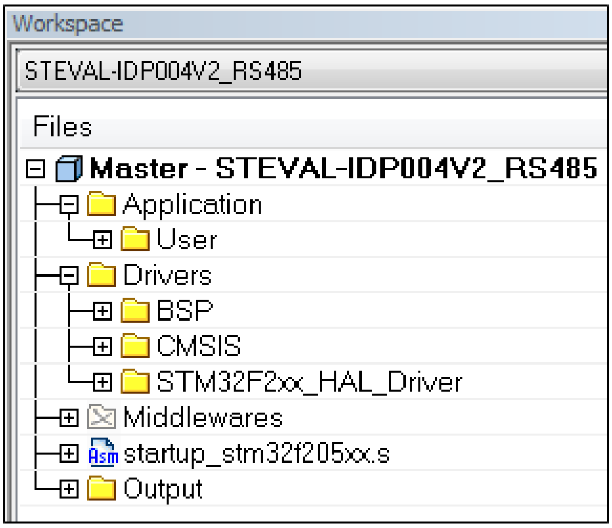
3.1.1 STEVAL-IDP004V2 evaluation firmware description

This firmware package manages RS-485/USB communication with a PC for STEVAL-IDP004V2 configuration and data exchange between the STEVAL-IDP004V2 and STEVAL-IDP003V1 through the IO-Link physical layer.

The following source files are included:

1. **PC_Communication_RS485**: with all the routines needed to manage command decoding and data exchange between the STEVAL-IDP004V2 and the PC
2. **PC_Communication_USB**: with all the routines needed to manage command decoding and data exchange between the STEVAL-IDP004V2 and the PC
3. **Master_Settings.c**: with the routines needed to configure all the L6360 ICs on the STEVAL-IDP004V2 master board
4. **Master_DeviceCOMM.c**: with all the routines used to exchange data between the STEVAL-IDP004V2 master board and the STEVAL-IDP003V1 sensor board.

Figure 18. **STEVAL-IDP004V2 evaluation firmware project related to RS-485 implementation**



At start-up, the master board is in the receiving state, waiting for a command sent by the user.

Following a START command, communication with master board is established and the STEVAL-IDP004V2 starts to interact with user, prompting for input regarding which board (master or device) to select.

Master board (STEVAL-IDP004V2) selected

In this case, the firmware prompts for:

1. address of the master IC
2. operating mode (Current Write, Current Read, Sequential Write, Sequential/Random Read); based on the selection, further specific information like register addresses and values are requested

If the programming mode is completed correctly, the message “Programming Done” or “Reading Done" is returned.

Once one or all the on-board L6360 devices are programmed, you can stop the configuration phase with “COMMAND END” command and query the STEVAL-IDP003V1 regarding the connected sensor with the “IDS” command to a particular node, and measured parameters with the “PRM” command.

The parameter value returned depends on which kind of sensor is connected to the device board (STEVAL-IDP003V1D):

- for the ToF VL6180X (STEVAL-IDP003V1P) sensor: distance from an object
- for the STTS751 (STEVAL-IDP003V1T) sensor: temperature in Celsius degrees
- for the accelerometer MEMS sensors:
  - for the IIS328DQ (STEVAL-IDP003V1A): acceleration for each axis in ‘mg’
  - for the IIS2DH (STEVAL-IDP003V1V): vibration for each axis in m/s^2

Once again you can stop communication with a sensor with “COMMAND END” or continue to query the same sensor with the “COMMAND NEW" command.

Device Node (STEVAL-IDP003V1) selected

In this case, the firmware prompts for the address of the related master IC:

- if the node is not programmed, the firmware will switch to the "Master board (STEVAL-IDP004V2) selected" routine, prompting the master node be requested before communication with the sensor.
- if the node is programmed, you can begin interacting with the sensor node to identify the connected sensor and receive measured parameter data.

For more details about the commands implemented to manage communication, please refer to the firmware data brief.

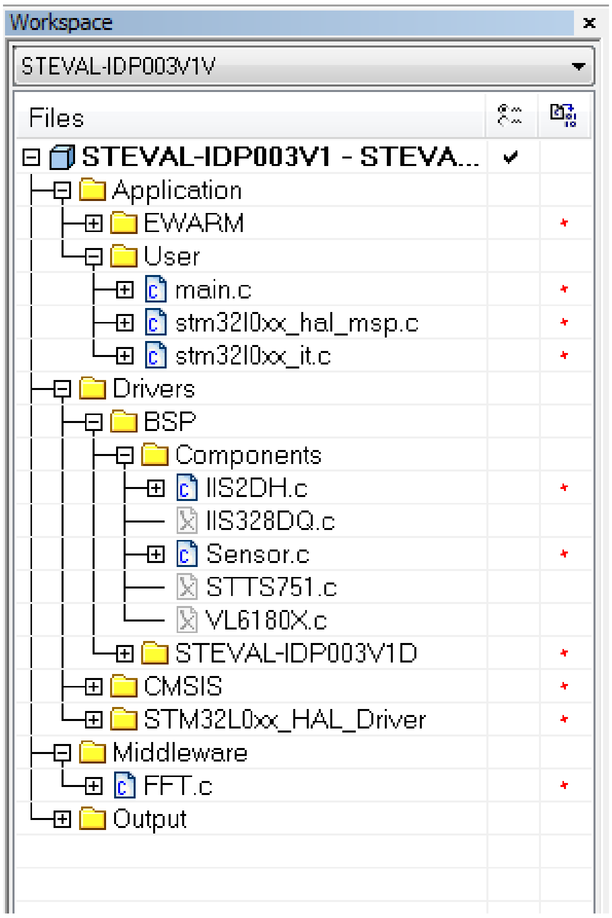
3.1.2 STEVAL-IDP003V1 evaluation firmware description

This firmware package manages communication through the IO-Link physical layer between the master node (STEVAL-IDP004V2) and sensor node (STEVAL-IDP003V1), as well as data exchange with the sensor board and subsequent processing.

The following source files are included:

1. **FFT.c**: with routines to perform vibration analysis with the MEMS IIS2DH sensor
2. **Sensor.c**: with routines for sensor configuration and data acquisition
3. **Master_DeviceCOMM.c**: with routines used to exchange data between the STEVAL-IDP004V2 master board and the STEVAL-IDP003V1 sensor board.

Figure 19. **STEVAL-IDP003V1 evaluation firmware project**



At start-up, the sensor board runs two processes in parallel:

- the first one keeps the sensor board on the IO-Link bus ready for a remote command
- the second one handles the sensor configuration and data acquisition as follows:
  1. after turn-on, the microcontroller proceeds with sensor configuration
  2. if it is completed correctly the “status_sensor” variable is changed from RESET to CONNECTED, otherwise it is changed to NOT CONNECTED
  3. if configuration ends correctly, the microcontroller continues with different data acquisition flows based on the connected sensor, as per the following list
- **Temperature sensor STTS751 and MEMS IIS328DQ**: parameter values are continuously updated in the corresponding structure.
- **Proximity sensor ToF VL6180X**: a remote command is requested to start the acquisition for a time slot defined by the variable STTPRX_MAX_SAMPLES in **Sensor.h**, when the acquisition is completed, the results are averaged and the updated structure is returned to the master.
- **MEMS IIS2DH**: this sensor is used for vibration monitoring through the continuous acquisition on interrupt event of each acceleration value of each accelerometer axis. When the number of samples acquired is equal to the value fixed by the defined variable FFT_SIZE in **FFT.h**, acquisition for that axis is stopped. The data is converted in m/s² and processed with dedicated routines in **FFT.c**. These routines implement the DSP library in the HAL library package to calculate the Fast Fourier Transform and evaluate vibration frequency and amplitude for each axis. The main routines used for vibration evaluation are `arm_rfft_fast_f32()arm_cmplx_mag_f32();` and `arm_max_f32().`

These functions take the sample input vectors and the FFT size setting to obtain an output vector with the index position in the array representing the ‘bin’ of a frequency value and the value stored at the same index position representing the amplitude of the corresponding frequency.

Once the output FFT vector has been obtained, the function `arm_max_f32()` extracts the maximum value and corresponding index and, using the reverse formula of the bin calculation: the input frequency is obtained when `SamplingFreq` is equal to accelerometer ODR.

3.2 Firmware package with IO-Link stack implementation

3.2.1 Firmware package for STEVAL-IDP004V2

This firmware package with IO-Link stack is available only in a compiled version which is preloaded in the microcontroller with level 1 readout protection (you can also download your own firmware into the microcontroller).

The stack embeds two different communication interfaces with host unit, USB and RS485.

The version is fully featured with time limitation (10000 minutes): after this time expires, the system stops working and a new license is necessary to run the system again. To get the new free license, it is necessary to contact the stack provider (TEConcept GmbH) and provide them the hardware ID which can be read using the Control Tool, a GUI developed by the same provider.

Data transmission between master and device node is managed using the Process Data features as written in the IO-Link stack standard.

Data received by the master are shown on the host processor using the Control Tool allowing data visualization and plotting: page format changes according to the information reported in the IODD file.

For the STEVAL-IDP004V2, four different IODDs have been released to show the data received by each sensor node, connected to the board (for further details, refer to UM2232 on www.st.com).

Data shown are:

- distance
- temperature
- inclination
- vibration (frequency and amplitude)

3.2.2 Firmware package for STEVAL-IDP003V1

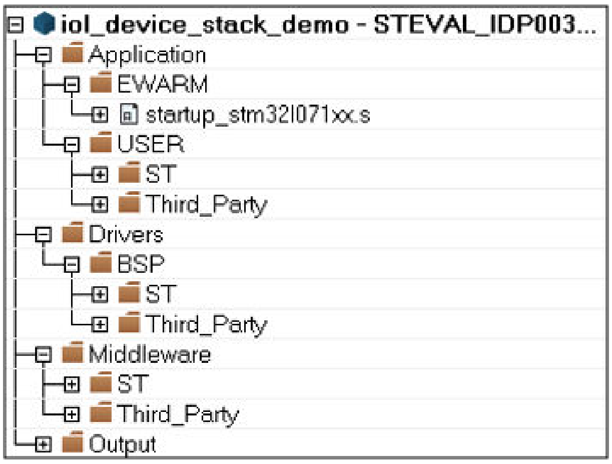
This package integrates the IO-Link stack library developed by TEConcept within the IO-Link consortium.

The stack is provided in a compiled version (iol_ds_as_lib.a) and with customizable APIs available in the header file (iold_api.h).

The stack code embedded is limited in execution time and features. Time limitation prevents stack use for more than 180 minutes; when this time expires, a hardware reset is necessary to restart the application. Feature limitation, instead, is related to missed implementation of sensor data storage, block transfer and BLOB.

The firmware architecture is based on the STM32Cube Ecosystem guidelines with an *Application* layer, a *Middleware* layer, a *Drivers* layer including BSP (board support package) and a HAL driver library.

Figure 20. STEVAL-IDP003V1 stack architecture



4 Functionality test with customized protocol

To perform a typical application test:

1. Connect each STEVAL-IDP004V2 IO-Link port to a STEVAL-IDP003V1D sensor node
2. Provide DC supply voltage in the range of 19 to 32 V through the STEVAL-IDP004V2 CON1 connector
3. Connect the ST-LINK/V2 programmer to the board J4 20-pin connector using the flat cable
4. Flash the STEVAL-IDP004V2-RS485.hex file in the microcontroller using the STM32 ST-LINK Utility
5. Connect the ST-LINK/V2 to the J1 connector with an adapter to the STEVAL-IDP003V1
6. Flash the firmware related to the sensor connected on board using STM32 ST-LINK Utility
7. Remove the programmer and reset the STEVAL-IDP004V2

If the STEVAL-IDP004V2 green LED starts blinking and the STEVAL-IDP003V1 green LED is ON or blinking, the kit is working properly.

After microcontroller programming, you can use a HyperTerminal (or Tera Term) interface to interact with the hardware, performing Read/Write operations on the L6360 ICs or, after L6360 programming, send commands to the STEVAL-IDP003V1 to identify the connected sensor and the measured parameter.

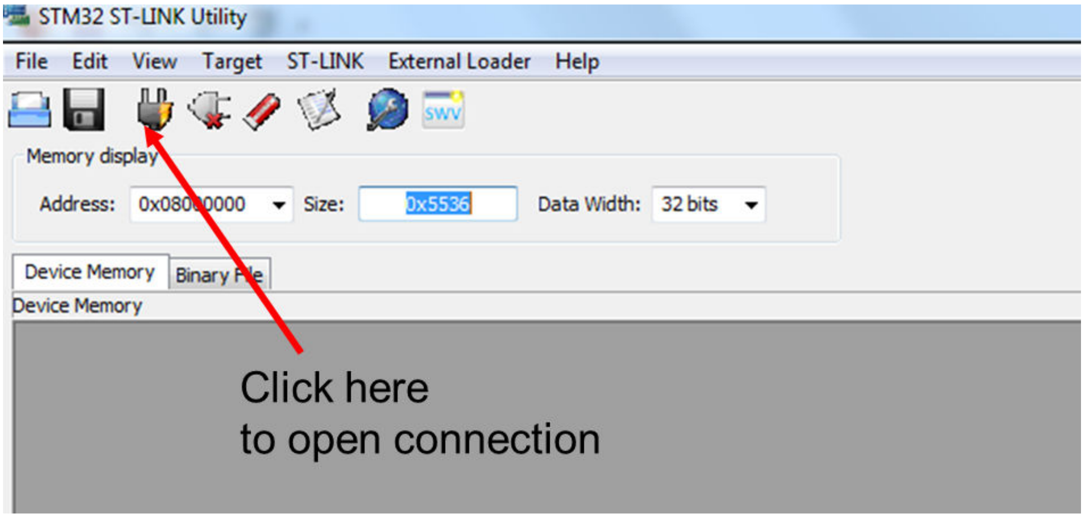
4.1 Microcontroller programming procedure

The programming procedure can be performed with the STM32 ST-LINK Utility programming tool.

After the ST-LINK/V2 programmer has been connected to the STEVAL-IDP004V2 J4 connector:

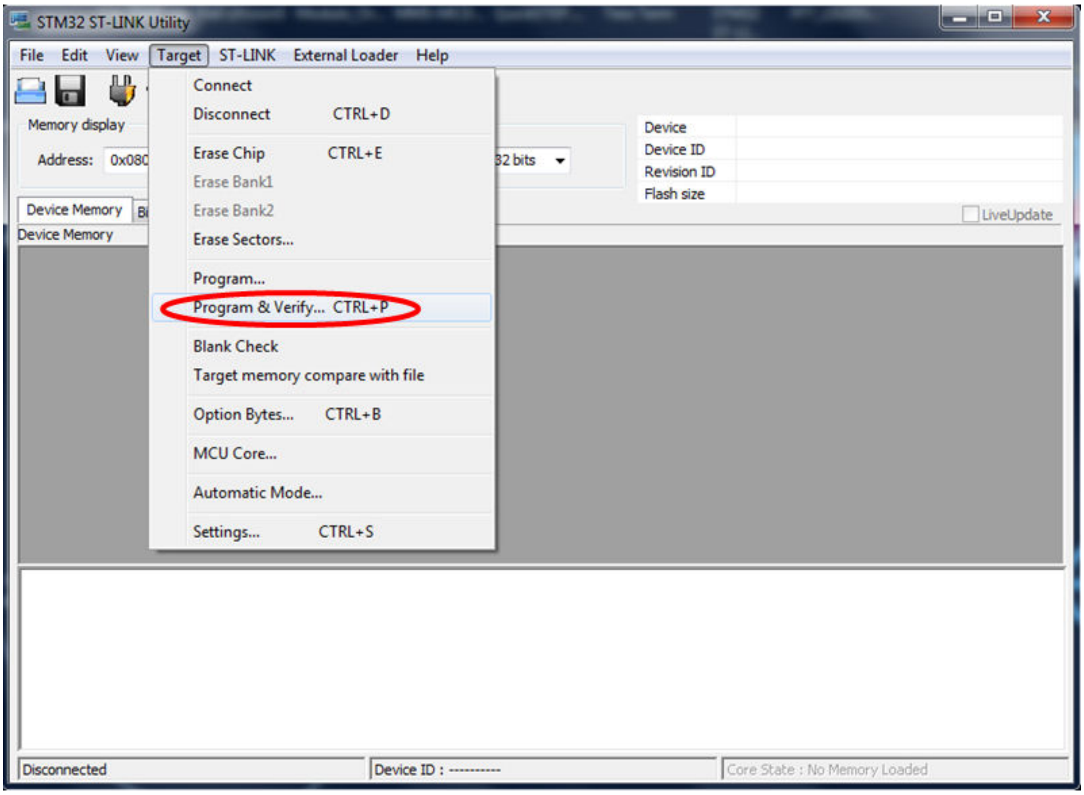
1. Open the tool and press the toolbar connection button. The microcontroller memory first reading results should appear.

Figure 21. STM32 ST-LINK Utility



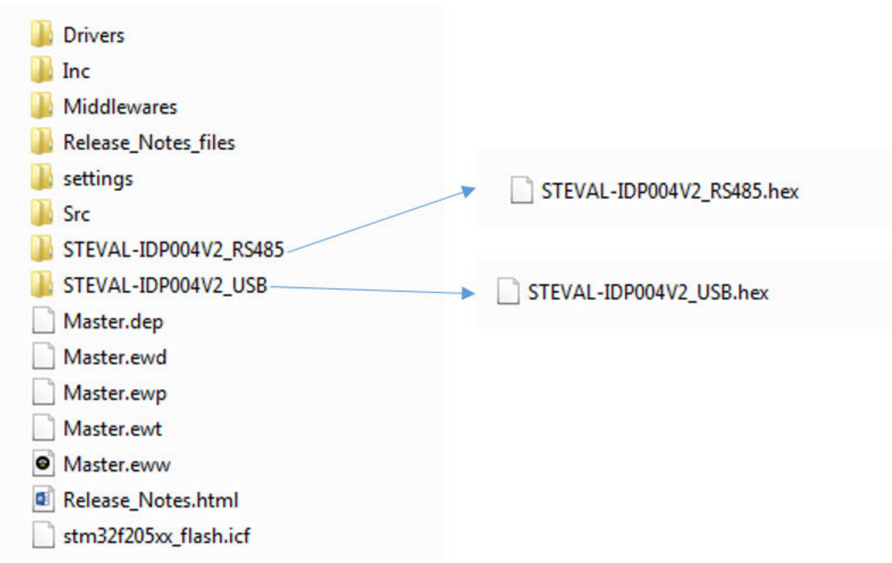
2. Then select [**Target**]>[**Program & Verify**]

Figure 22. **STM32 ST-LINK program and verify menu**



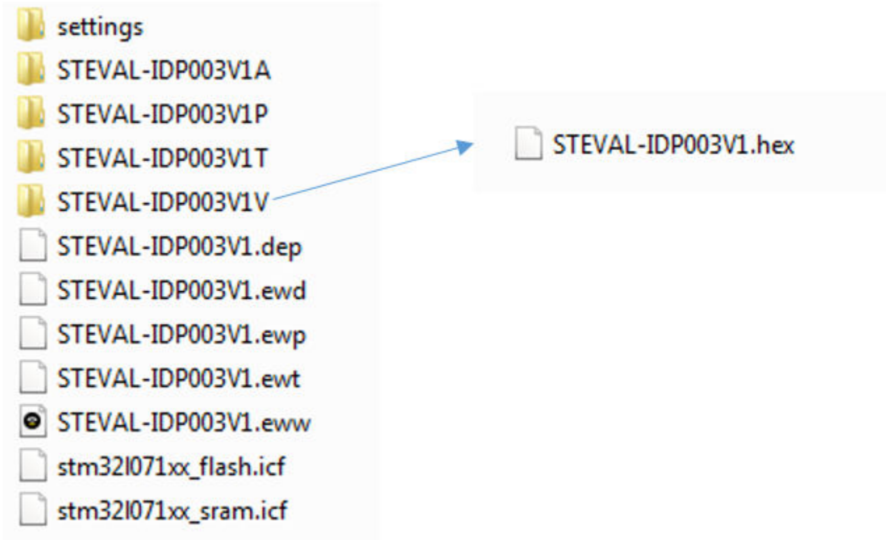
3. Click [**Browser**] and select the .hex in the STEVAL-IDP004V2 folder

Figure 23. **STEVAL-IDP004V2 folder with STEVAL-IDP004V2.hex**



4. Click [**Start**] and program the board.
   The same procedure must be followed to program the STEVAL-IDP003V1, but here it is necessary to select the appropriate Slave Node sub folder according to the sensor.

Figure 24. Sensor folder with STEVAL-IDP003V1.hex

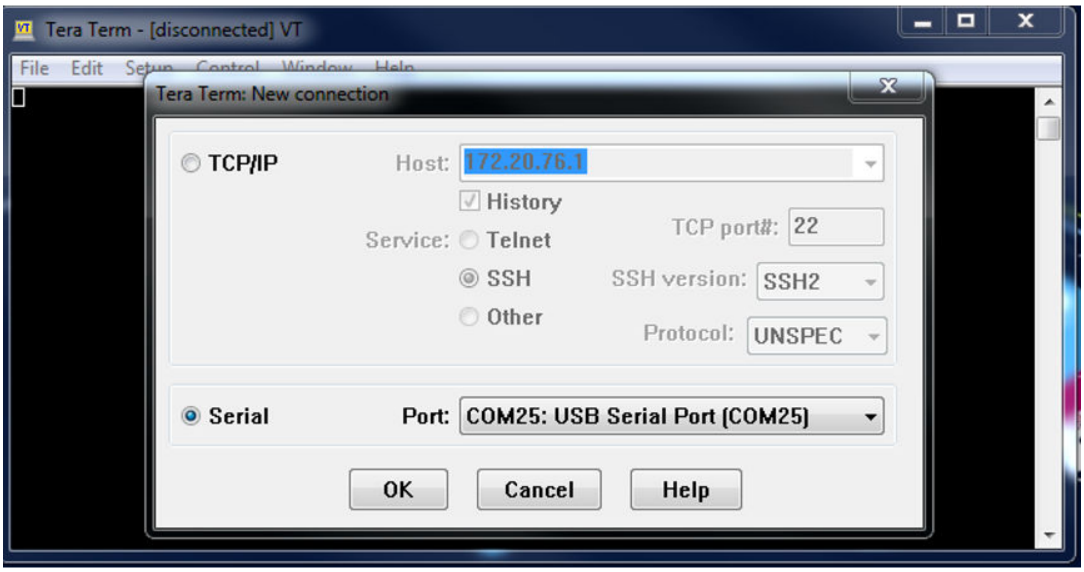


4.2 PC interface

Tera Term or Putty HyperTerminal interfaces can be used to perform programming procedures and remote sensor data acquisition using RS-485 interface as well as USB communication. According to the communication chosen, it is necessary to compile different firmware solutions:

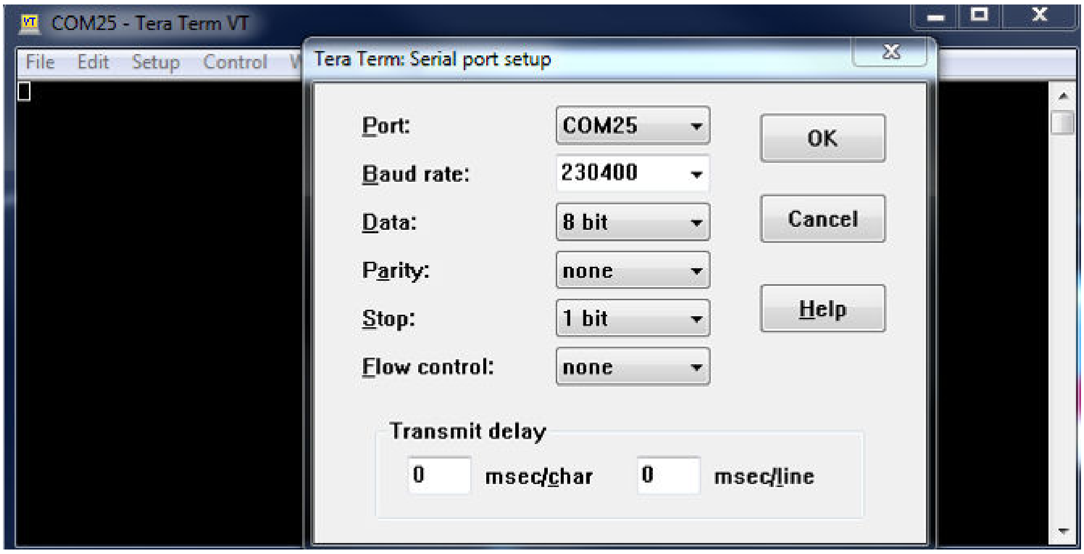
- once both boards are powered and programmed, connect the dongle (USB-RS485)
- connect the serial COM port

Figure 25. COM port connection with Tera Term



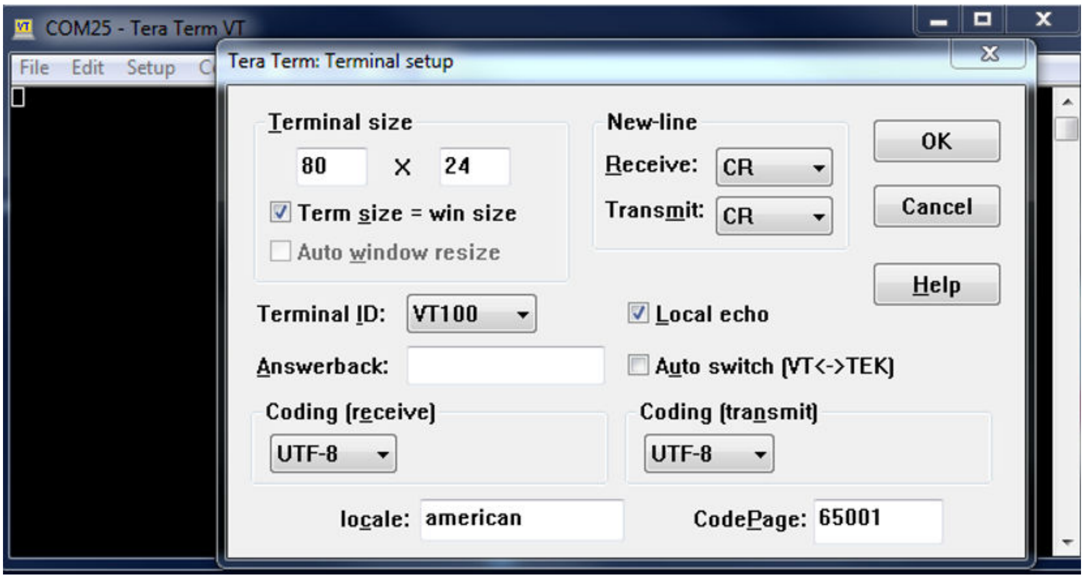
- Configure the serial communication parameters based on STEVAL-IDP004V2 settings:
  - Baud rate = 230400
  - Word length = 8 bit
  - Stop bits = 1
  - Parity = NONE
  - Flow Control = NONE

Figure 26. **COM port settings**



- Configure Terminal and check the “Local Echo” box

Figure 27. **Terminal settings**



After performing the steps above, you can start communication:

1. Send START command
2. Digit Master and click enter
3. Insert Master IC address using number from 0 to 3
4. Insert the operating mode in this format:
   – WR_C for write current
   – WR_S for write sequential
   – RD_C for read current
   – RD_S for read sequential
5. Based on the operating mode chosen, different information is required:
   – For WR_C, insert:
     a. Register address in decimal format
     b. Register value in decimal format with comma character at the end
     c. A programming completion confirmation should appear
   – For WR_S, insert:
     a. All register values, in three-digit format, with a comma between each value and at the end
     b. A programming completion confirmation should appear
   – For RD_C:
     a. The L6360 Status register value is shown
     b. The reading done message appears
6. Following the programming procedure, run the communication with the STEVAL-IDP003V1
   a. Type the command “COMMAND END”
   b. Type “DEVICE” and click enter
   c. Type “IDS” and click enter
   d. After the sensor responds, type “PRM”
   e. After sensor responds, either close the communication with the selected sensor with “COMMAND END”, or digit "COMMAND NEW" and then continue with the “PRM” command for further data acquisition.

The codeblock below shows an example of STEVAL-IDP004V2 programming.

```
SELECT MASTER OR DEVICE
MASTER
INSERT ADDRESS IC:
0
INSERT OPERATING MODE:
WR_C
INSERT REGISTER ADDRESS:
5
INSERT REGISTER VALUE:
152,
PROGRAMMING DONE

COMMAND NEW
INSERT ADDRESS IC:
0
INSERT OPERATING MODE:
WR_S
INSERT REGISTER VALUE:
096,122,033,122,122,122,122,
PROGRAMMING DONE


COMMAND NEW
INSERT ADDRESS IC:
0
INSERT OPERATING MODE:
RD_C

Status register   128
READING DONE
```

```
COMMAND NEW
INSERT ADDRESS IC:
2
INSERT OPERATING MODE:
WR_C
INSERT REGISTER ADDRESS:
1
INSERT REGISTER VALUE:
096,
PROGRAMMING DONE


COMMAND NEW
INSERT ADDRESS IC:
2
INSERT OPERATING MODE:
RD_S
INSERT REGISTER ADDRESS:
0
Status register   128
Configuration register    96
Control 1    33
Control 2    33
LED 1 MSB    0
LED 1 LSB    0
LED 2 MSB    0
LED 2 LSB    0
Parity register   128
READING DONE
```

The codeblock below shows an example of STEVAL-IDP004V2 to STEVAL-IDP003V1 communication.

```
SELECT MASTER OR DEVICE
DEVICE
INSERT SENSOR COMMAND: IDS
SENSOR ID: VL6180X
CONNECTED
INSERT SENSOR COMMAND: PRM
SENSOR ID: VL6180X
DISTANCE 46 mm
COMMAND END

SELECT MASTER OR DEVICE
DEVICE
INSERT SENSOR COMMAND: IDS
SENSOR ID: STTS751
CONNECTED
INSERT SENSOR COMMAND: PRM
SENSOR ID: STTS751
TEMPERATURE: 28.7168 Celsius degree
COMMAND END


SELECT MASTER OR DEVICE
DEVICE
INSERT SENSOR COMMAND: IDS
SENSOR ID: IIS2DH
CONNECTED
INSERT SENSOR COMMAND: PRM
SENSOR ID: IIS2DH
VIBRATION X,Y,Z: 1950Hz  0.13M/s2   ;  1971Hz   0.08m/s2   ;   1950Hz 0.25M/s2   ;
COMMAND END

SELECT MASTER OR DEVICE
DEVICE
INSERT SENSOR COMMAND: IDS
SENSOR ID: IIS328DQ
CONNECTED
```

```
INSERT SENSOR COMMAND: PRM
SENSOR ID: IIS328DQ
ACCELERATION X,Y,Z: 517,  -35,  915,  mg
```

5 Functionality test with IO-Link stack

To perform a typical application test on the stack:

Step 1. Connect the STEVAL-IDP003V1 to the STEVAL-IDP004V2 and supply the system using the CON1 on STEVAL-IDP004V2

Step 2. Open TEConcept Control tool

Step 3. Connect the STEVAL-IDP004V2 to the PC

Step 4. Select the right IODD and supply the STEVAL-IDP003V1 board

Step 5. Connect the Control tool to the STEVAL-IDP004V2 and supply the STEVAL-IDP003V1 (see Section 5.2: How to use TEConcept Control Tool for details)

Step 6. Flash the firmware related to the sensor board using STM32 ST-LINK Utility

5.1 Microcontroller programming procedure

Follow the microcontroller programing procedure only for the STEVAL-IDP003V1D board, as the STEVAL-IDP004V2 has been already programmed with the IO-Link stack.

The steps necessary to program the board through the STM32 ST-LINK Utility are the same as described in the previous section: the only difference is that the firmware package to use is the version with stack.

Once the programming procedure is completed, use TEConcept Control Tool to read and plot the sensor measured data.

5.2 How to use TEConcept Control Tool

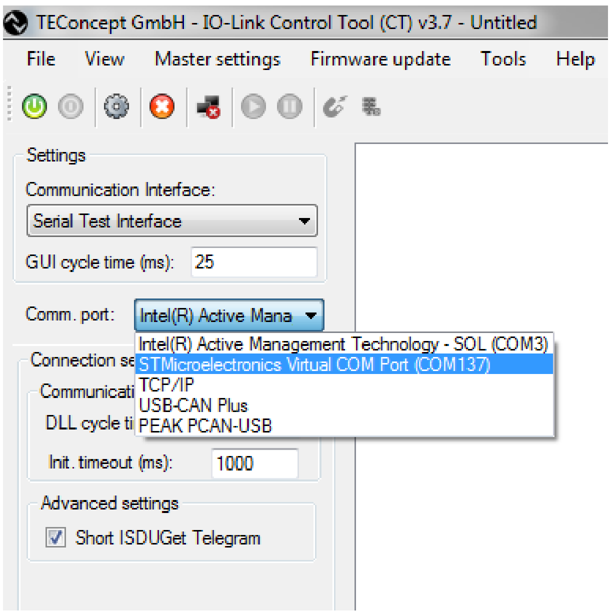
The STEVAL-IDP004V2 with the master stack can be managed by the user via TEConcept Control Tool. Follow the procedure below to enable communication.

Step 1. Connect the STEVAL-IDP004V2 to the PC via USB or RS485 connector

Step 2. Provide the supply voltage to the board

Step 3. Open the Control Tool and select the virtual COM port related to the board in the Comm. port menu

Figure 28. TEConcept Control Tool: virtual COM port selection



Step 4. Click on the green button to start communication

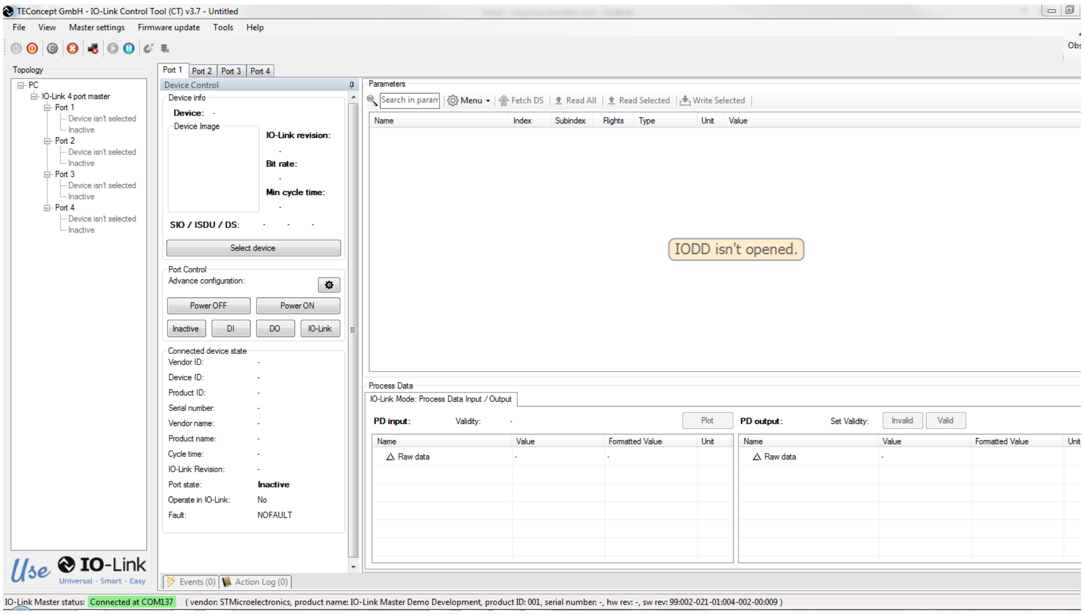


Figure 29. **TEConcept Control Tool: active connection**

Step 5. Click on [**Select device**]

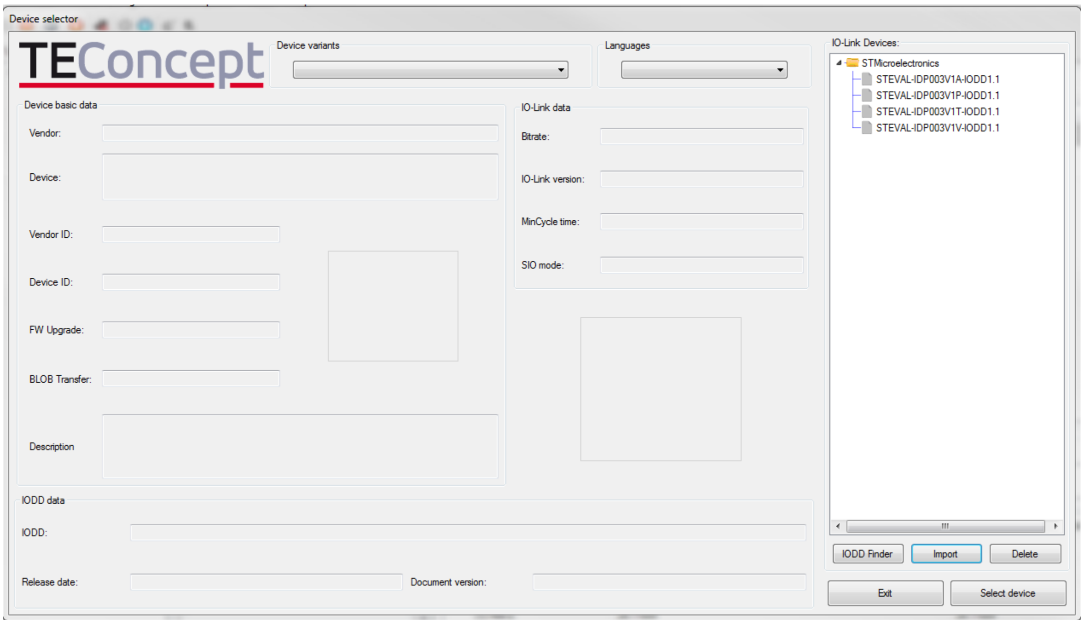


Figure 30. **TEConcept Control Tool: device selection**

Step 6. Click [**Import**] to import the relevant IODD file, and then double click on the IODD to select it

Step 7. Click [**IO-Link**] (on the right) to connect the node and display the plot

Figure 31. **TEConcept Control Tool: node connection**

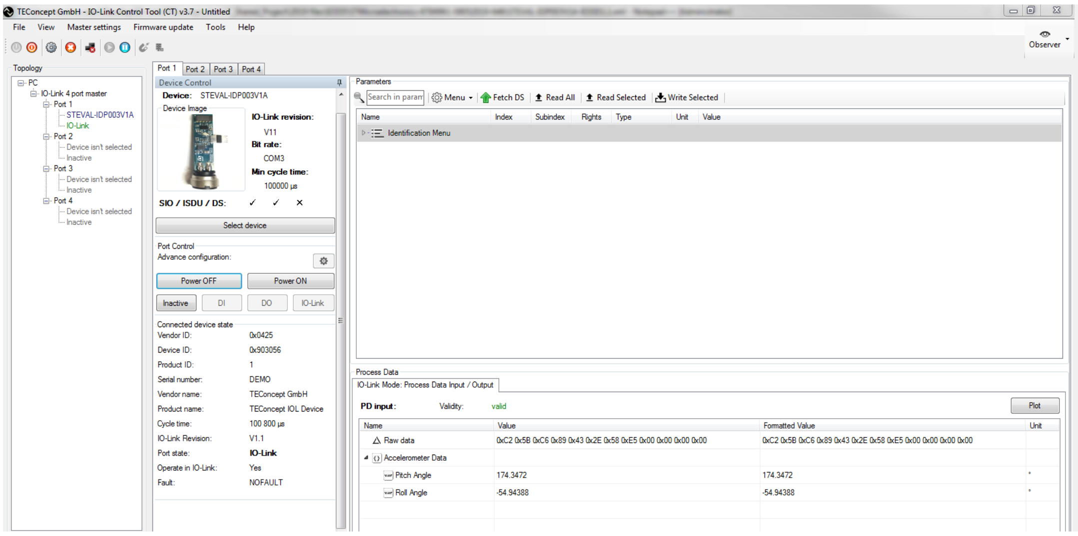
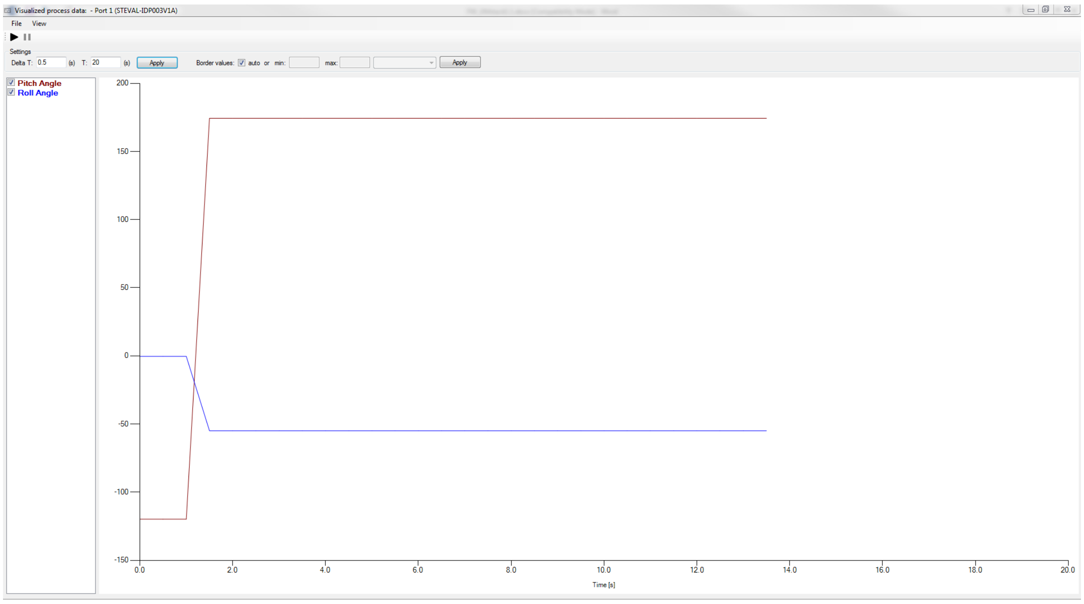


Figure 32. **TEConcept Control Tool: data plot**



6 STEVAL-IDP003V1 schematic diagrams

Figure 33. **STEVAL-IDP003V1 circuit schematic (1 of 6) - step-down switching regulator**

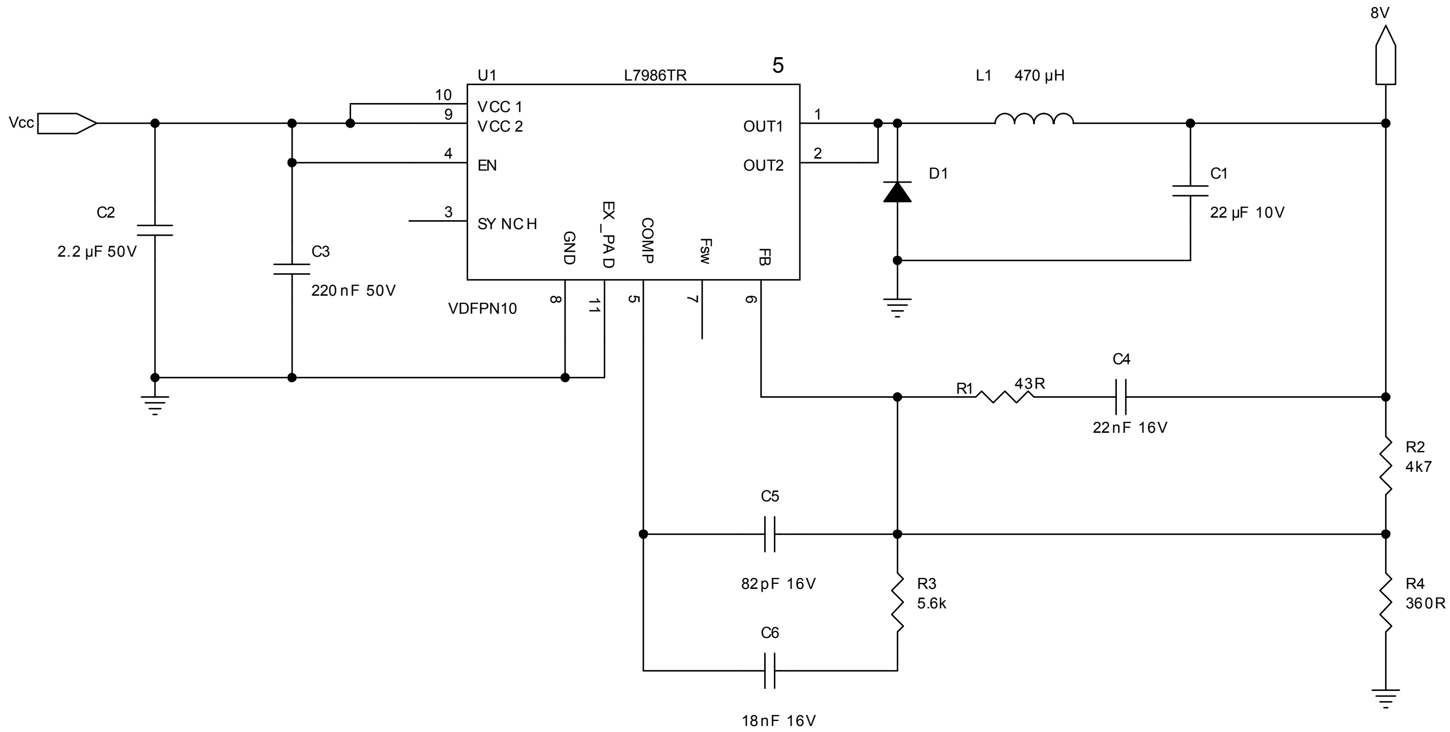


Figure 34. STEVAL-IDP003V1 circuit schematic (2 of 6) - vibration sensor

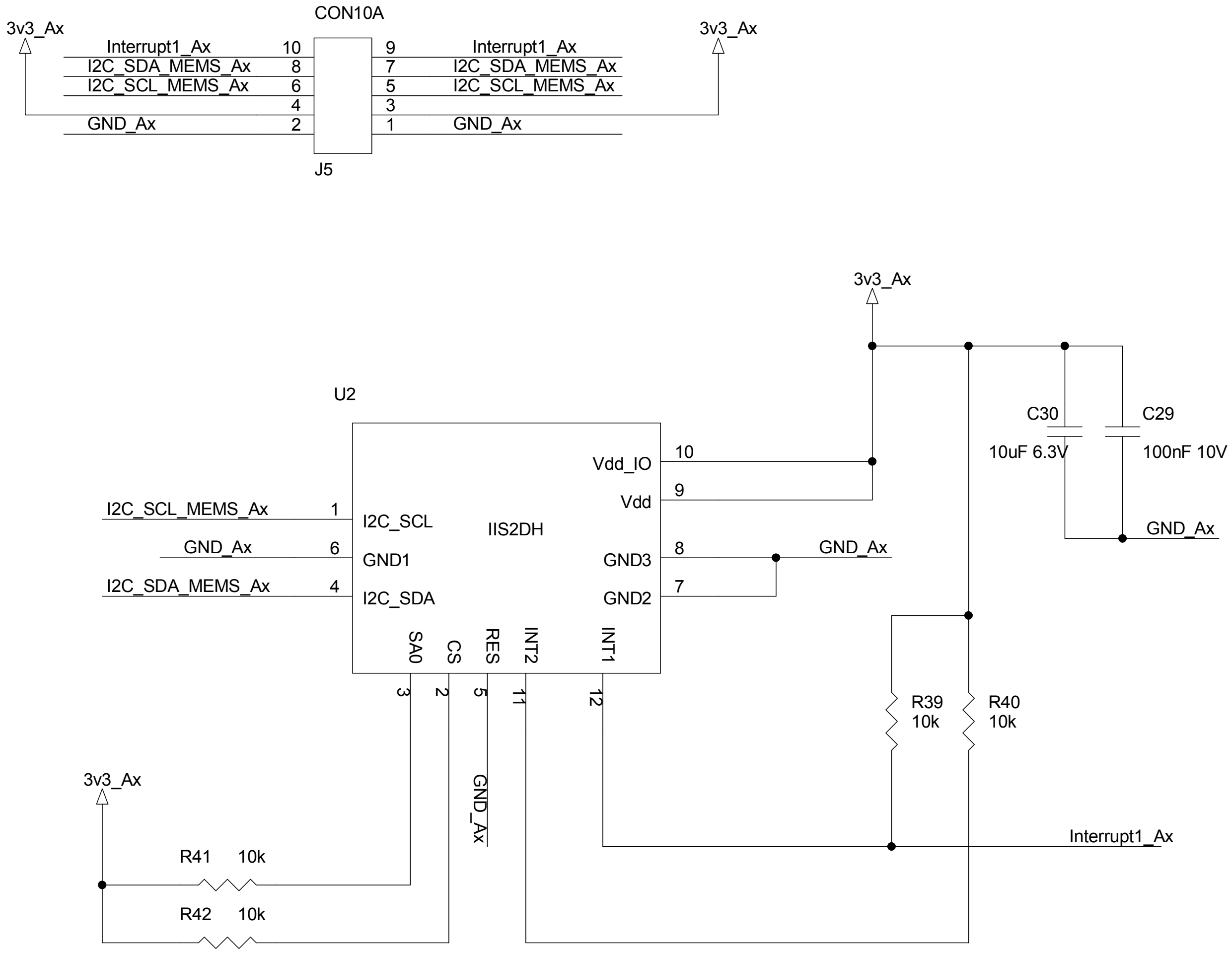


Figure 35. STEVAL-IDP003V1 circuit schematic (3 of 6) - accelerometer sensor

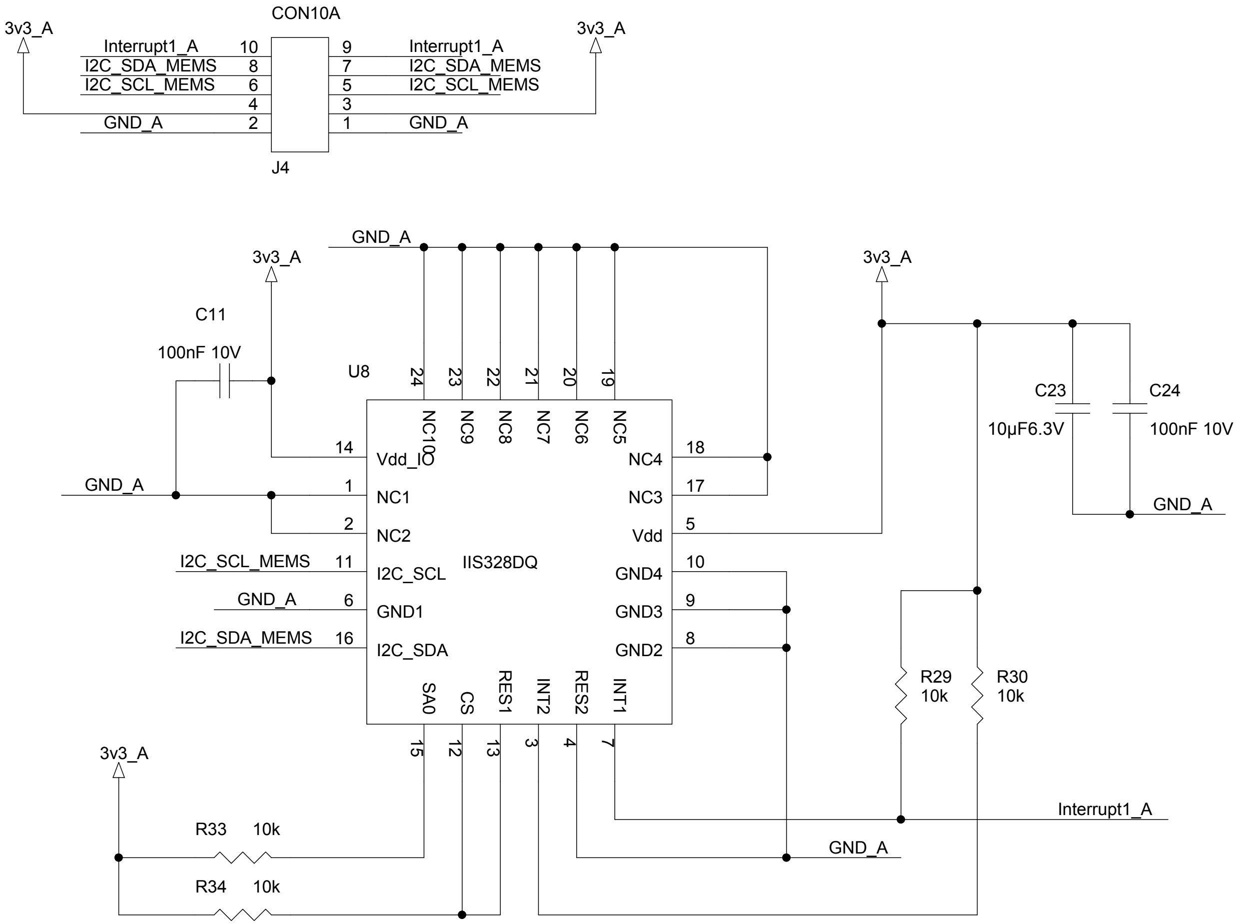


Figure 36. STEVAL-IDP003V1 circuit schematic (4 of 6) - temperature sensor

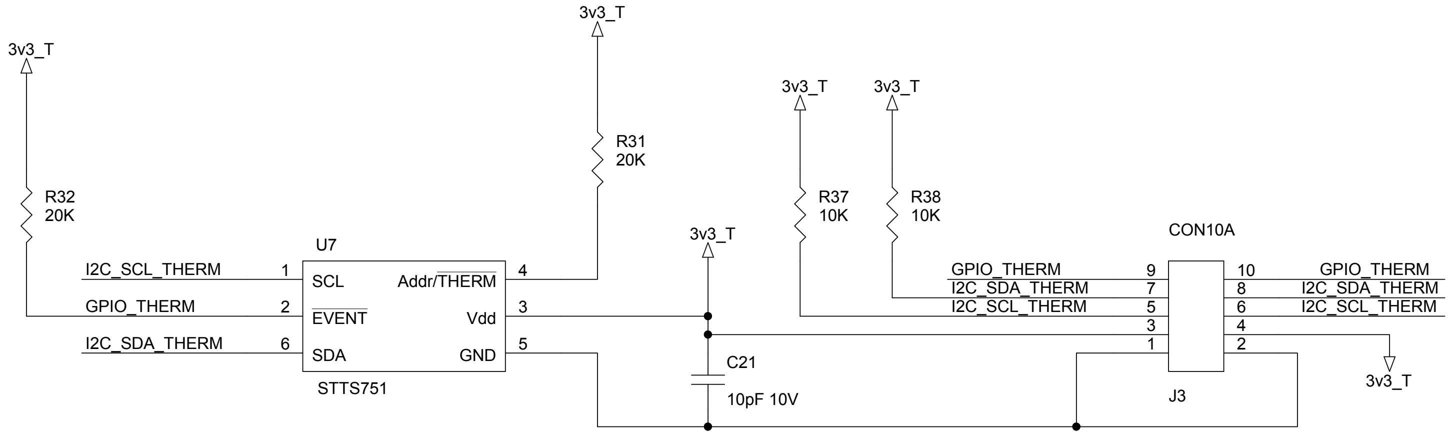


Figure 37. STEVAL-IDP003V1 circuit schematic (5 of 6) - proximity sensor

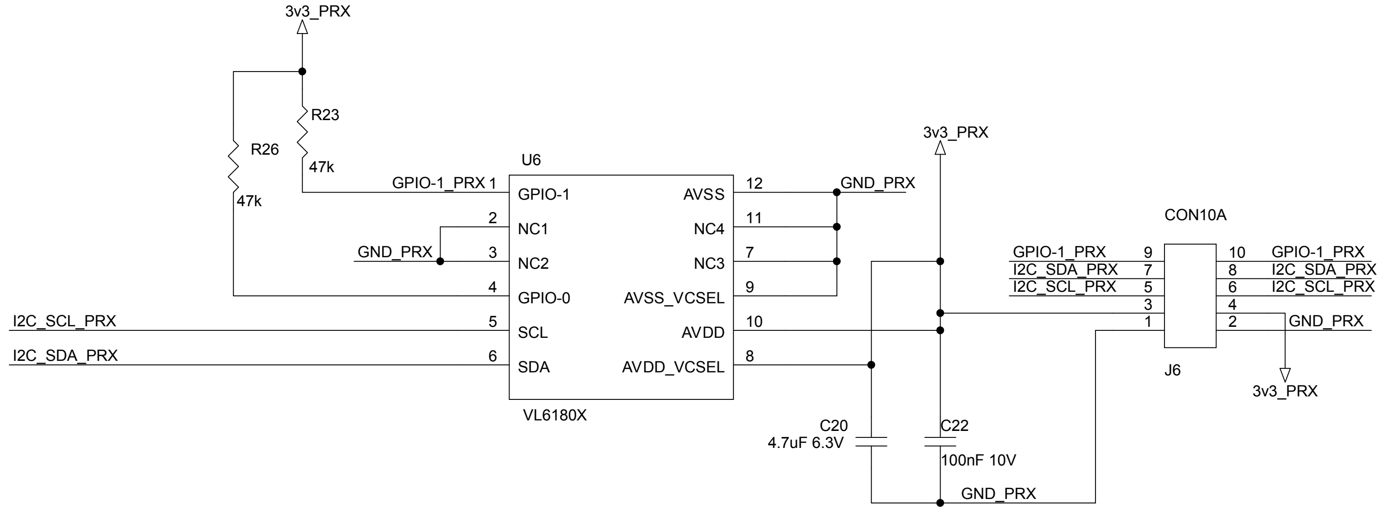
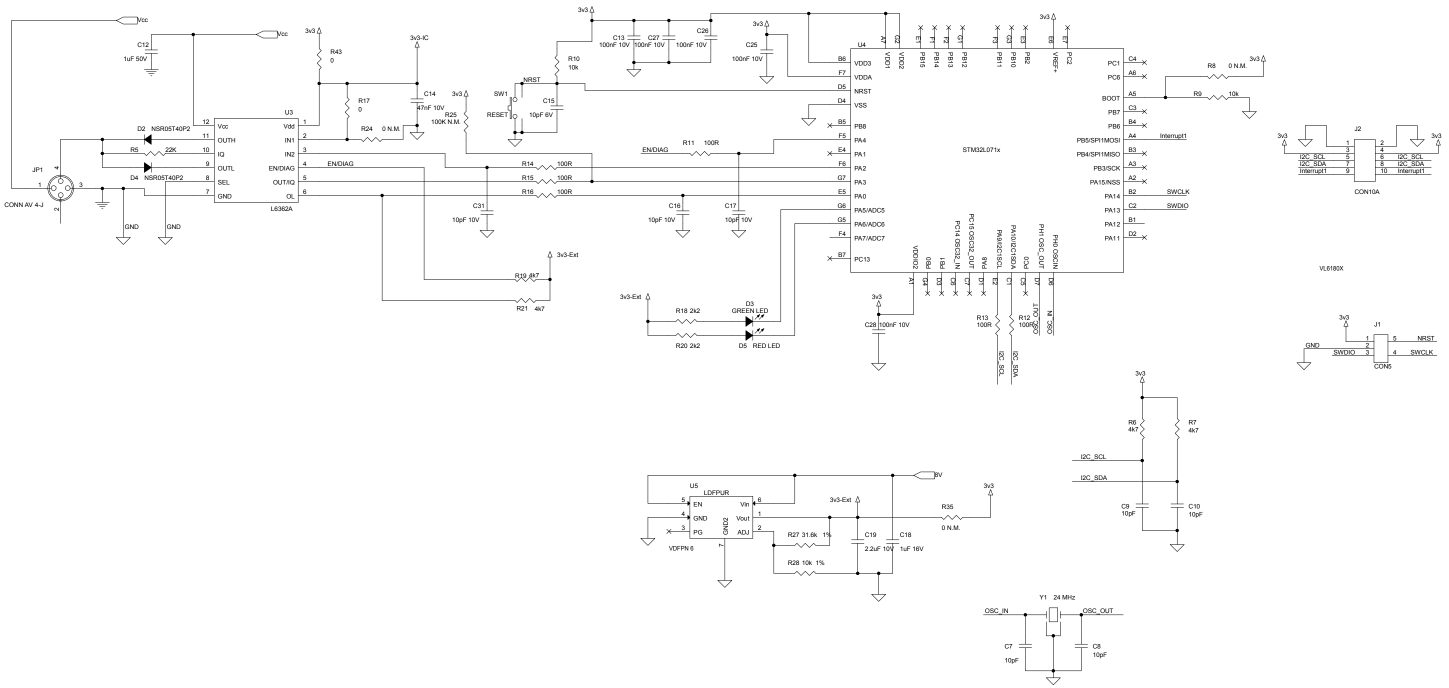


Figure 38. STEVAL-IDP003V1 circuit schematic (6 of 6) - microcontroller



7 STEVAL-IDP003V1 bill of materials

Table 3. STEVAL-IDP003V1 evaluation board bill of materials

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
1	2	C1	22 µF 10 V ±20% SMD 0805	X5R ceramic capacitor	Any	Any
2	1	C2	2.2 µF 50 V ±20% SMD 0805	X7R ceramic capacitor	Any	Any
3	1	C3	220 nF 50 V ±10% SMD 0603	X7R ceramic capacitor	Any	Any
4	1	C4	22 nF 16 V ±10% SMD 0402	X7R ceramic capacitor	Any	Any
5	1	C5	82 pF 16 V ±10% SMD 0402	X7R ceramic capacitor	Any	Any
6	1	C6	18 nF 16 V ±10% SMD 0402	X7R ceramic capacitor	Any	Any
7	1	C12	1 µF 50 V ±10% SMD 0805	X7R ceramic capacitor	Any	Any
8	1	C14	47 nF 16 V ±10% SMD 0402	X7R ceramic capacitor	Any	Any
9	1	C18	1 µF 16 V ±10% SMD 0603	X7R ceramic capacitor	Any	Any
10	1	C19	2.2 µF 10 V ±10% SMD 0603	X7R ceramic capacitor	Any	Any
11	6	C7, C8, C9, C10, C15, C16, C17, C31	10 pF 10 V ±5% SMD 0402	C0G ceramic capacitor	Any	Any
12	5	C13, C25, C26, C27, C28	100 nF 10 V ±10% SMD 0402	X7R ceramic capacitor	Any	Any
13	1	D1	STPS1L60MF STmite flat (DO222-AA)	Low drop power Schottky rectifier in flat package	ST	STPS1L60MF
14	1	D5	2.3 V SMD 0603	Red LED	Any	Any
15	1	D3	2.3 V SMD 0603	Green LED	Any	Any
16	2	D2, D4	NSR05T40P2 SOD-923	Schottky barrier diode	On Semiconductors	NSR05T40P2T5G
17	1	JP1	M12 connector male TH		Binder	9043121204
18	1	J1	CON5 TH	5 way stripline male, pitch 1.27mm	Harwin Inc.	M52-040023V0545
19	1	J2	CON5 TH	10 way stripline male double row, pitch 1.27mm	Harwin Inc.	M50-3200545
20	1	L1	470 µH 140 mA SMD	Inductor	TDK	VLCF4028T-471MR14-2
21	1	R1	43 R ±1% SMD 0402	SMD Resistor	Any	Any

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
22	5	R6, R7, R2, R19, R21	4.7 k ±1% SMD 0402	SMD Resistor	Any	Any
23	1	R3	5.6 k ±1% SMD 0402	SMD Resistor	Any	Any
24	1	R4	360 R ±1% SMD 0402	SMD Resistor	Any	Any
25	3	R9, R10, R28	10k ±1% SMD 0402	SMD Resistor	Any	Any
26	2	R18, R20	2k2 ±1% SMD 0402	SMD Resistor	Any	Any
27	1	R27	31.6 k ±1% SMD 0402	SMD Resistor	Any	Any
28	6	R11, R12, R13, R14, R15, R16	100 R ±1% SMD 0402	SMD Resistor	Any	Any
29	2	R17, R35	0 E ±1% SMD 0402	SMD Resistor	Any	Any
30	3	R8, R24, R43	0 E ±1% SMD 0402	SMD Resistor	Any	Any
31	1	R25	100 k ±1% SMD 0402	SMD Resistor	Any	Any
32	1	R5	22 k ±1% SMD 0603	SMD Resistor	Any	Any
33	1	SW1	RESET SMD	Micro switch	C & K	KMR221GLFS
34		U1	L7986TR VFQFPN10 3 x 3 mm	3 A step-down switching regulator	ST	L7986TR
35	1	U3	L6362A DFN12 3x3mm	IO-Link communication transceiver device IC	ST	L6362ATR
36	1	U4	STM32L071CZY6 WLCSP49	Access line ultra-low-power 32-bit MCU	ST	STM32L071CZY6
37	1	U5	LDFPUR DFN6 3x3mm	1 A very low drop voltage regulator	ST	LDFPUR
38	1	Y1	24MHZ SMD 2.50x2.00 mm	Crystal	Abracon LLC	ABM10AIG-24.000MHZ-4Z-T3

Table 4. **Sensor board bill of materials**

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
1	4	C11, C22, C24, C29	100 nF 10 V ±10% SMD 0402	X7R ceramic capacitor	Any	Any
2	1	C20	4.7 µF 6.3 V ±10% SMD 0603	X5R ceramic capacitor	Any	Any
3	1	C21	10 pF 6.3 V ±10% SMD 0402	X7R ceramic capacitor	Any	Any
4	2	C23,C30	10 µF 6.3 V ±10% SMD 0603	X5R ceramic capacitor	Any	Any
5	4	J3, J4, J5, J6	CON5 TH	5x2 way stripline male, pitch 1.27mm	Any	Any
6	10	R29, R30, R33, R34, R37, R38, R39, R40, R41, R42	10 k ±1% SMD 0402	SMD Resistor	Any	Any
7	2	R23, R26	47 k ±1% SMD 0402	SMD Resistor	Any	Any
8	2	R31, R32	20 k ±1% SMD 0402	SMD Resistor	Any	Any
9	1	U2	IIS2DH LGA-12	3-axis digital accelerometer, ultra low-power high performance MEMS motion sensor	ST	IIS2DHTR
10	1	U6	VL6180X OPTICAL LGA12	Proximity sensor, gesture and ambient light sensing (ALS) module	ST	VL6180XV0NR/1
11	1	U7	STTS751 UDFN-6L	U2.25 V low-voltage local digital temperature sensor	ST	STTS751-1DP3F
12	1	U8	IIS328DQ QFN 24	3-axis accelerometer for industrial applications, SPI/I2C digital output, ultra low-power high performance	ST	IIS328DQTR

8 STEVAL-IDP004V2 schematic diagrams

Figure 39. STEVAL-IDP004V2 circuit schematic (1 of 11)

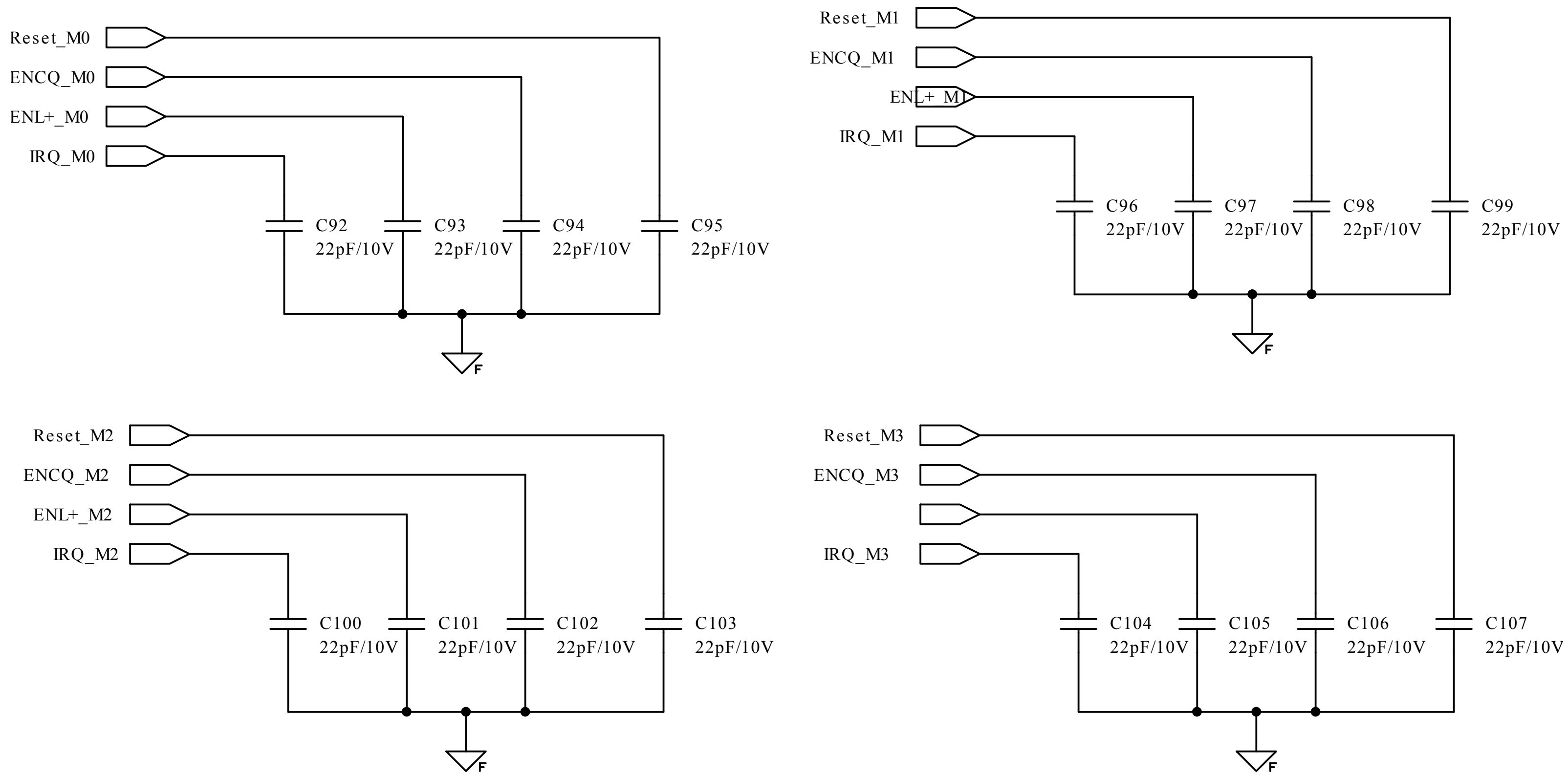


Figure 40. STEVAL-IDP004V2 circuit schematic (2 of 11)

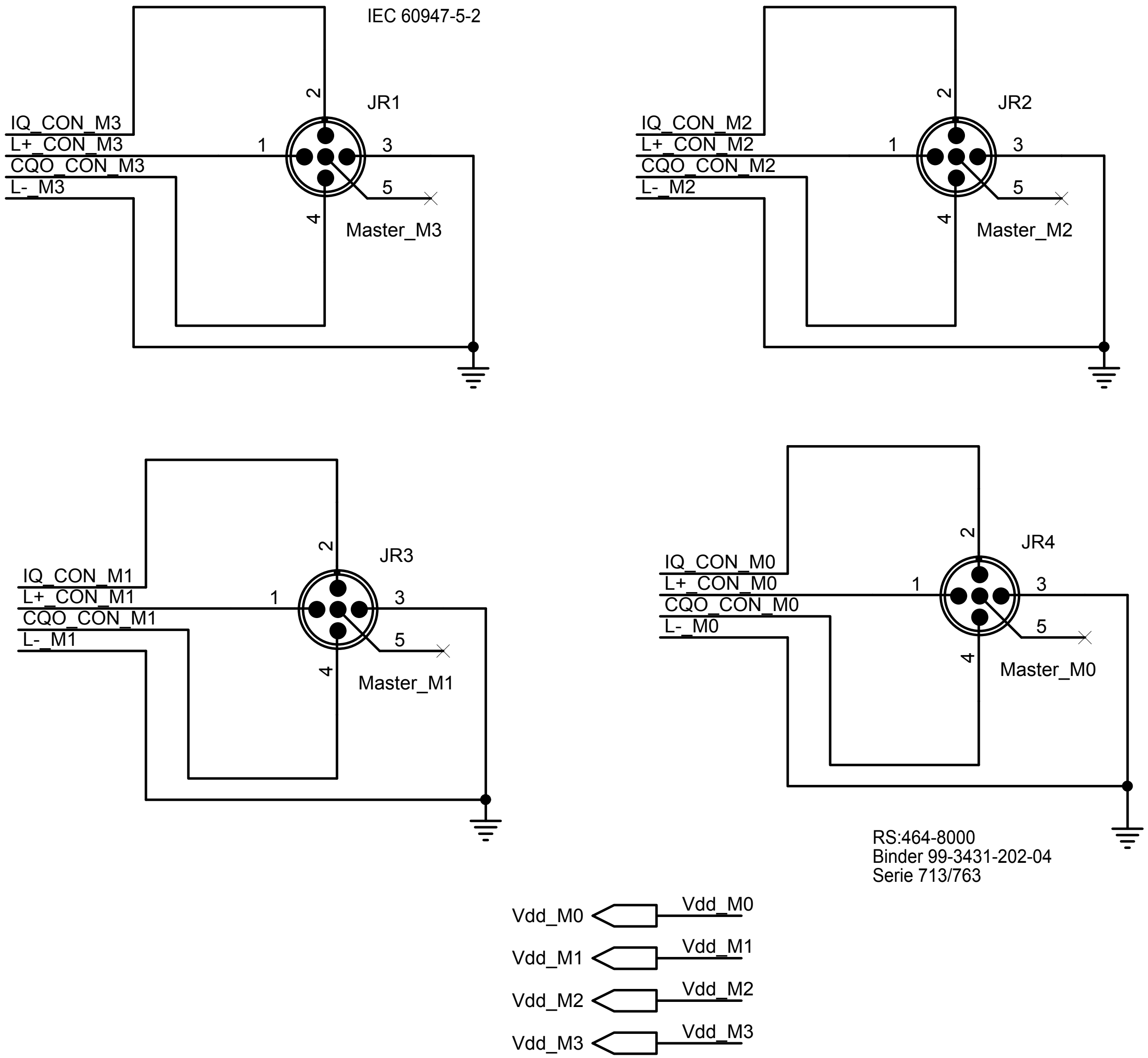


Figure 41. STEVAL-IDP004V2 circuit schematic (3 of 11)

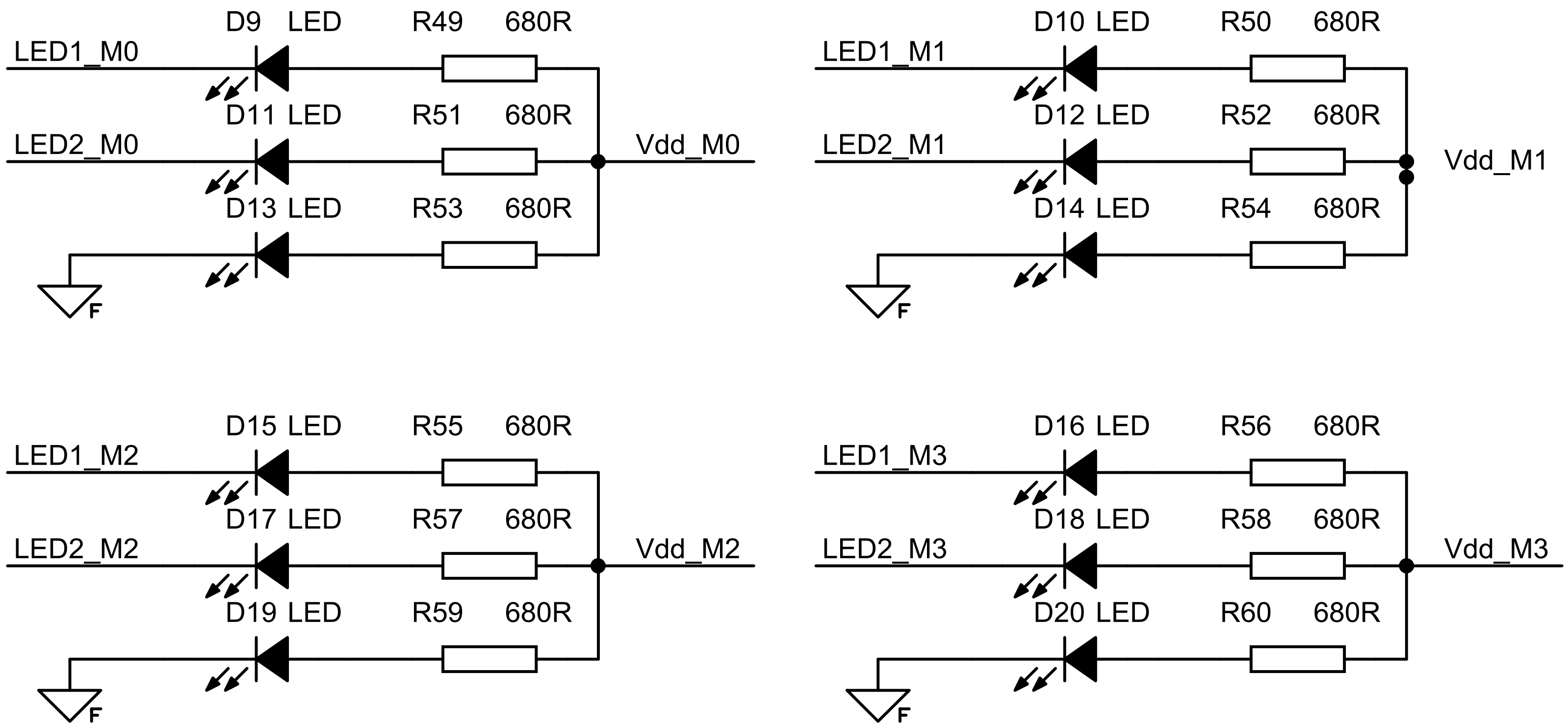


Figure 42. STEVAL-IDP004V2 circuit schematic (4 of 11)

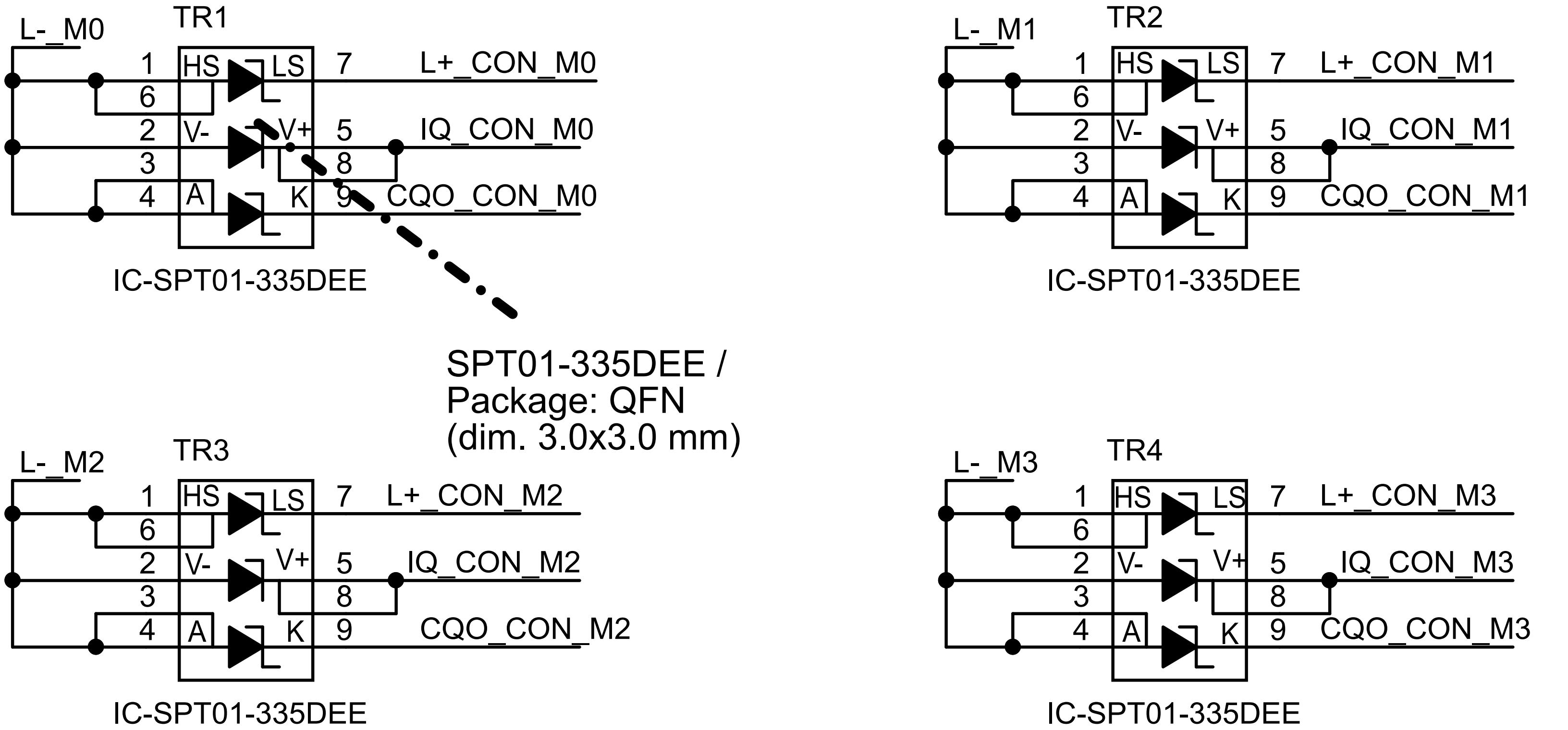


Figure 43. STEVAL-IDP004V2 circuit schematic (5 of 11)

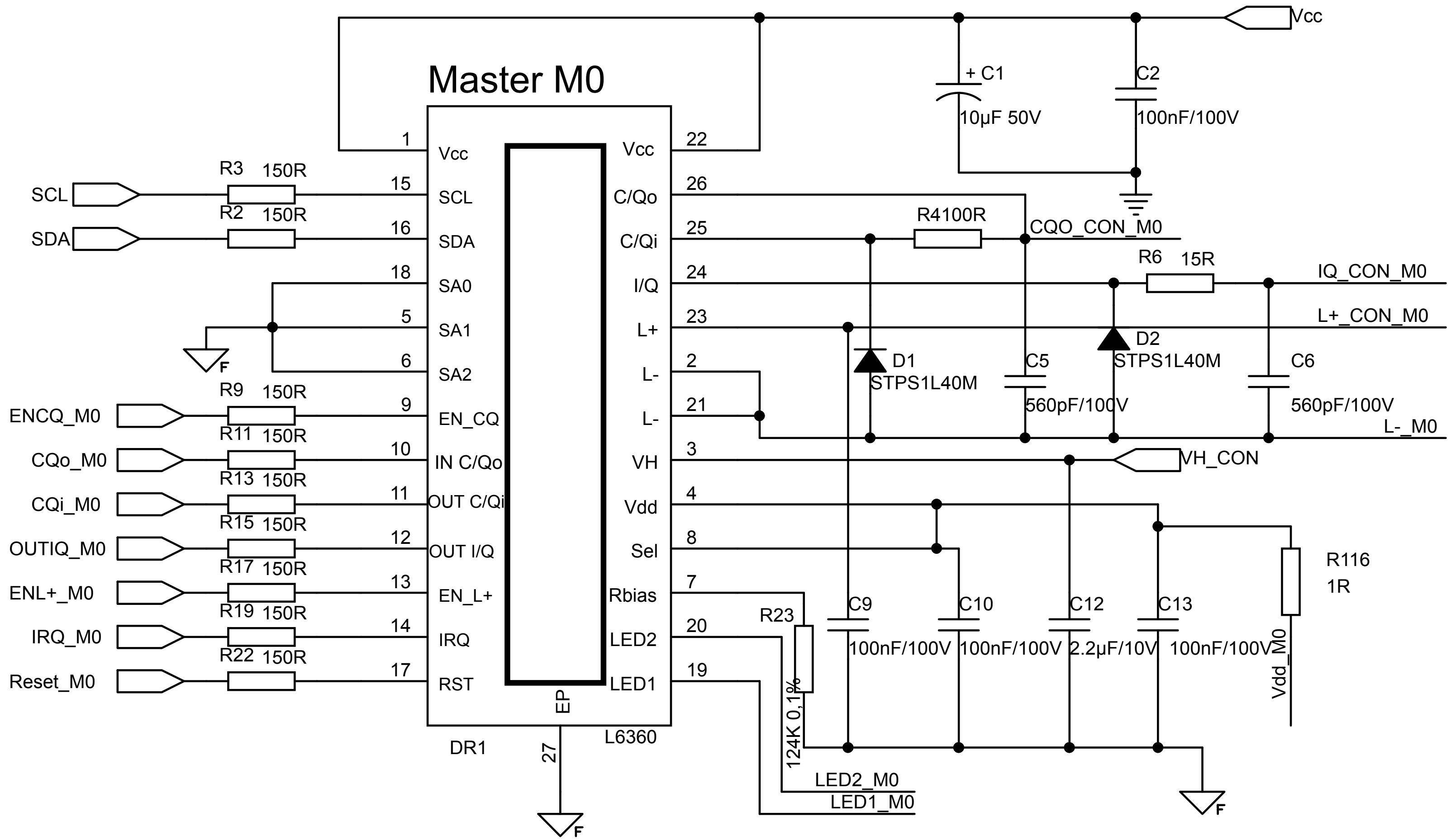


Figure 44. STEVAL-IDP004V2 circuit schematic (6 of 11)

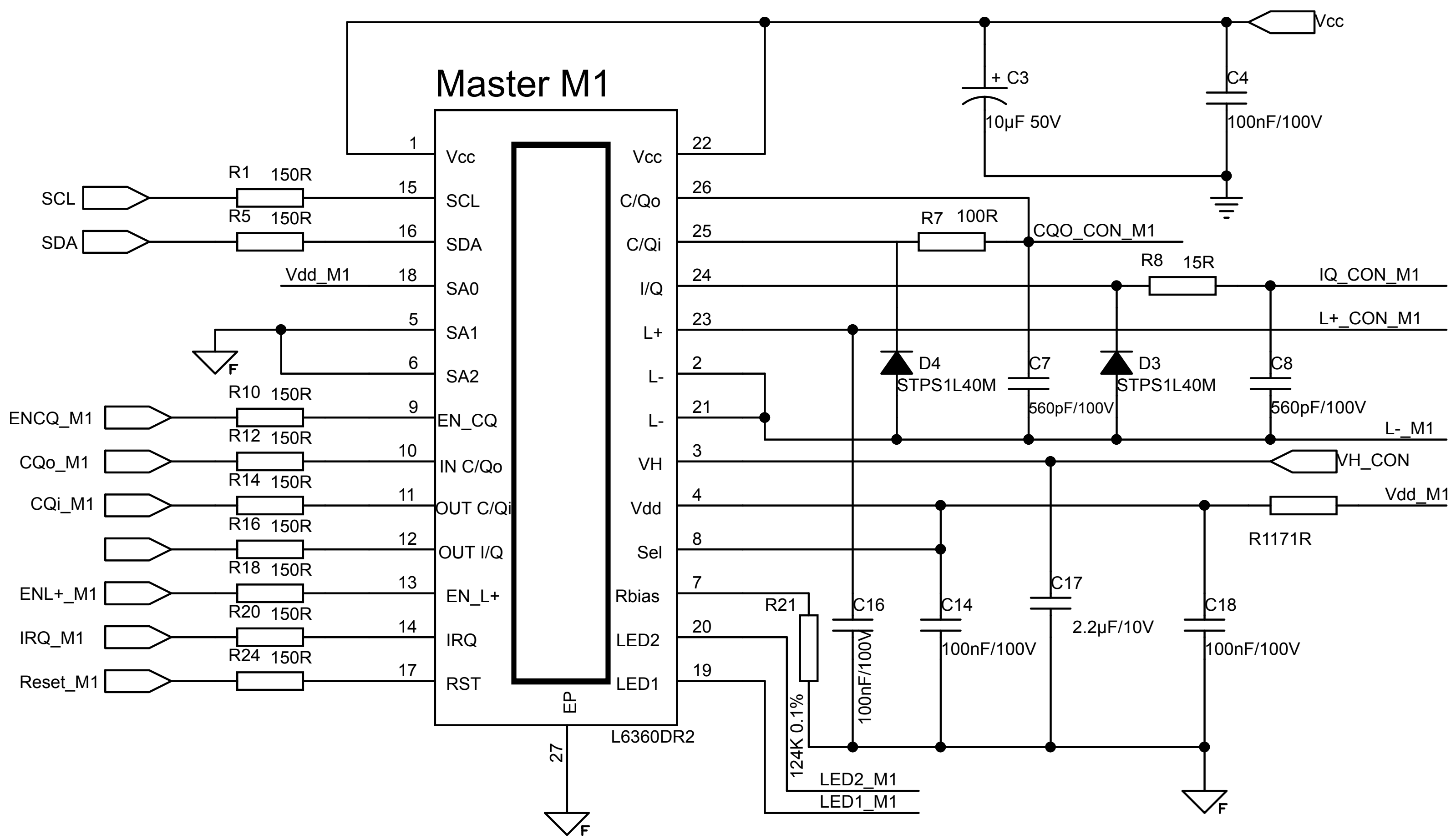


Figure 45. **STEVAL-IDP004V2 circuit schematic (7 of 11)**

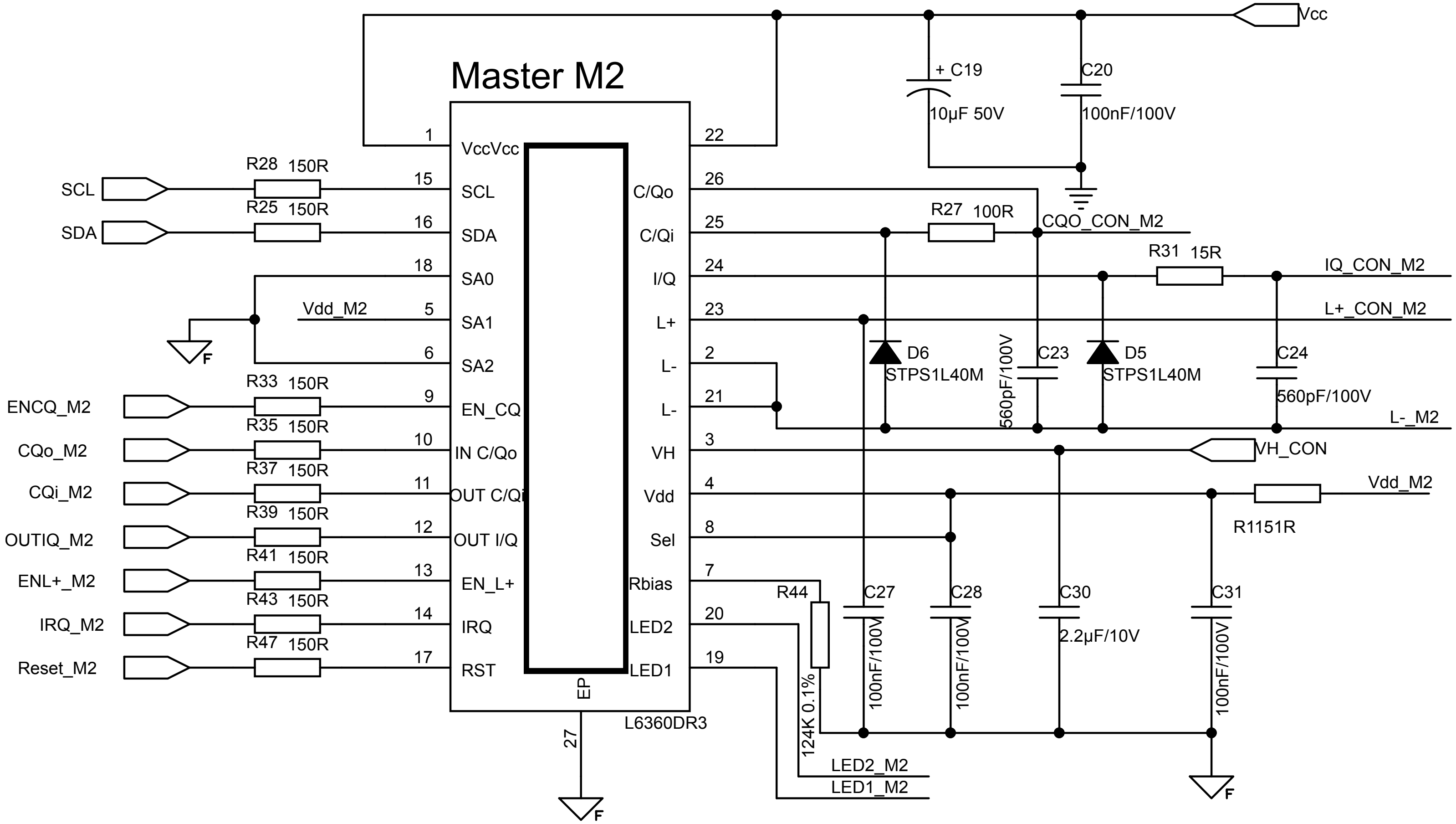


Figure 46. **STEVAL-IDP004V2 circuit schematic (8 of 11)**

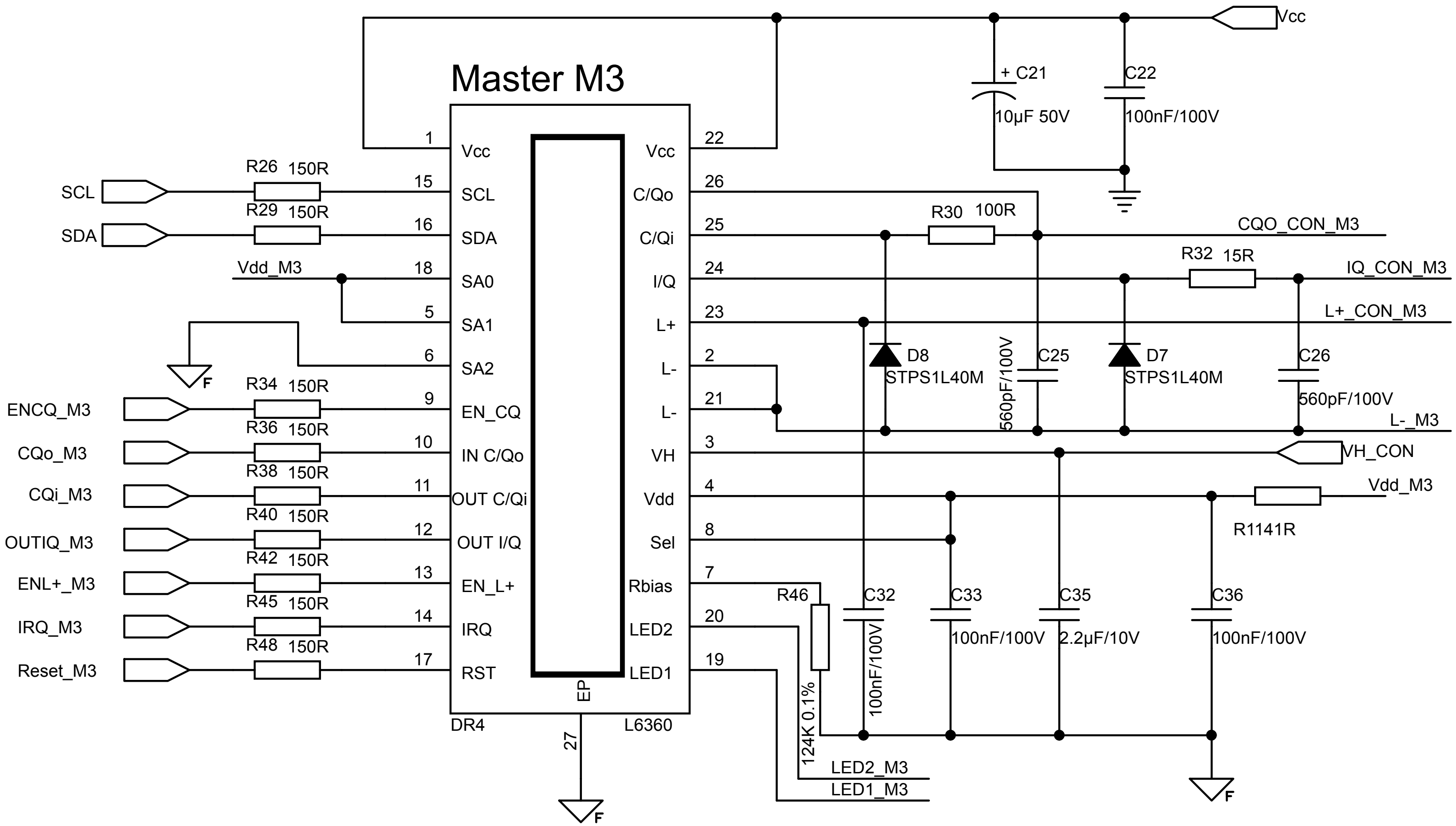


Figure 47. STEVAL-IDP004V2 circuit schematic (9 of 11)

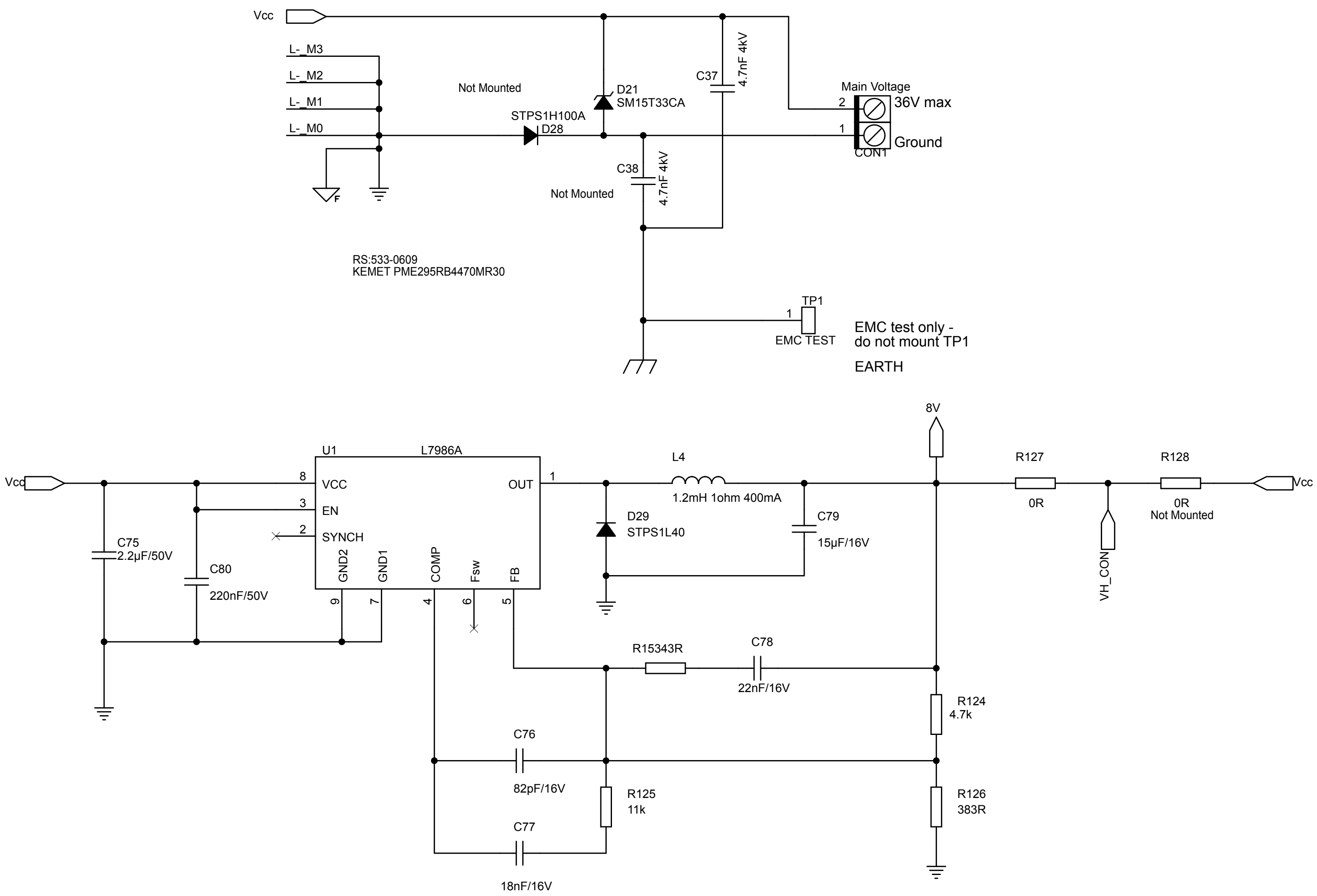


Figure 48. STEVAL-IDP004V2 circuit schematic (10 of 11)

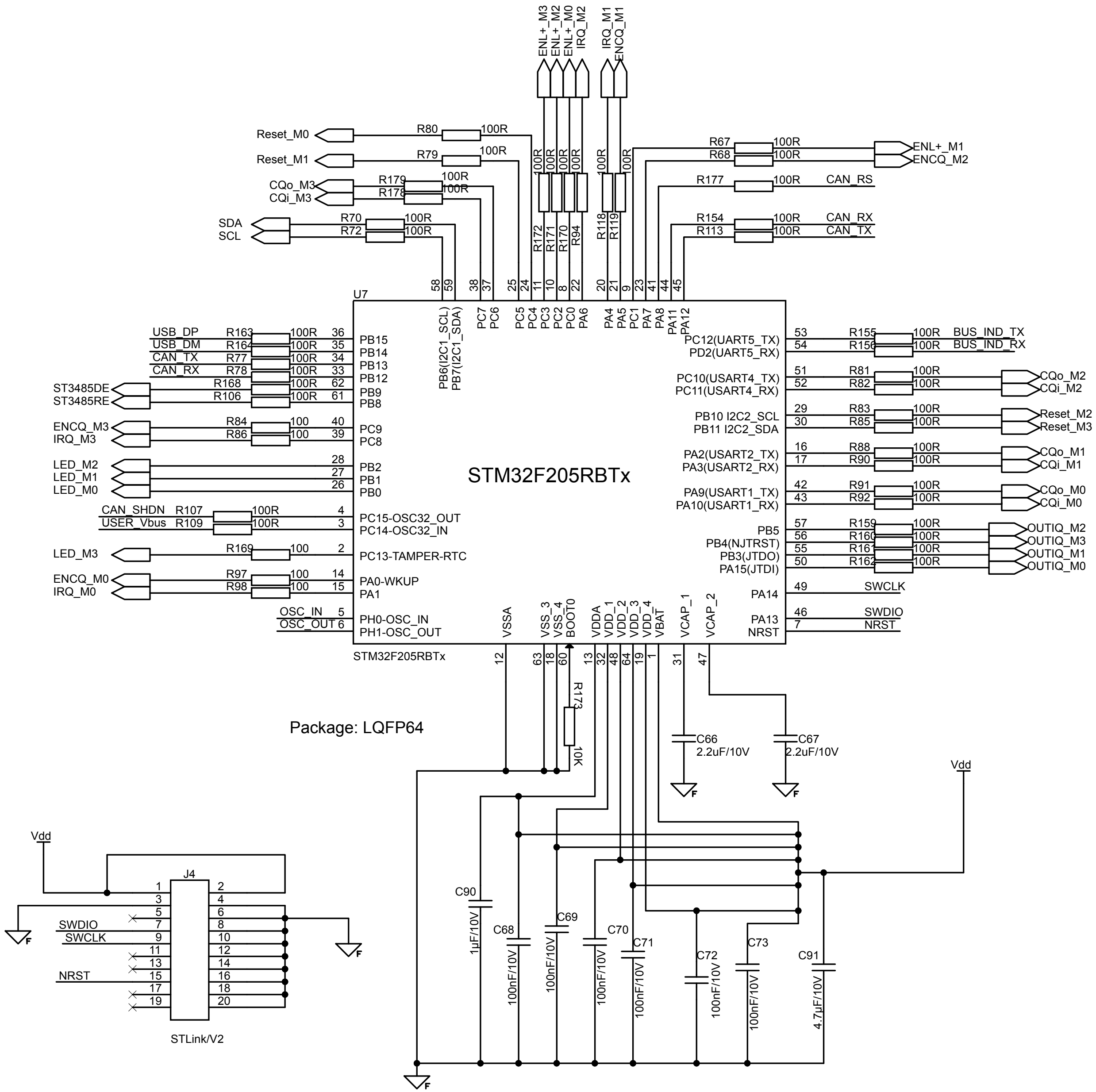
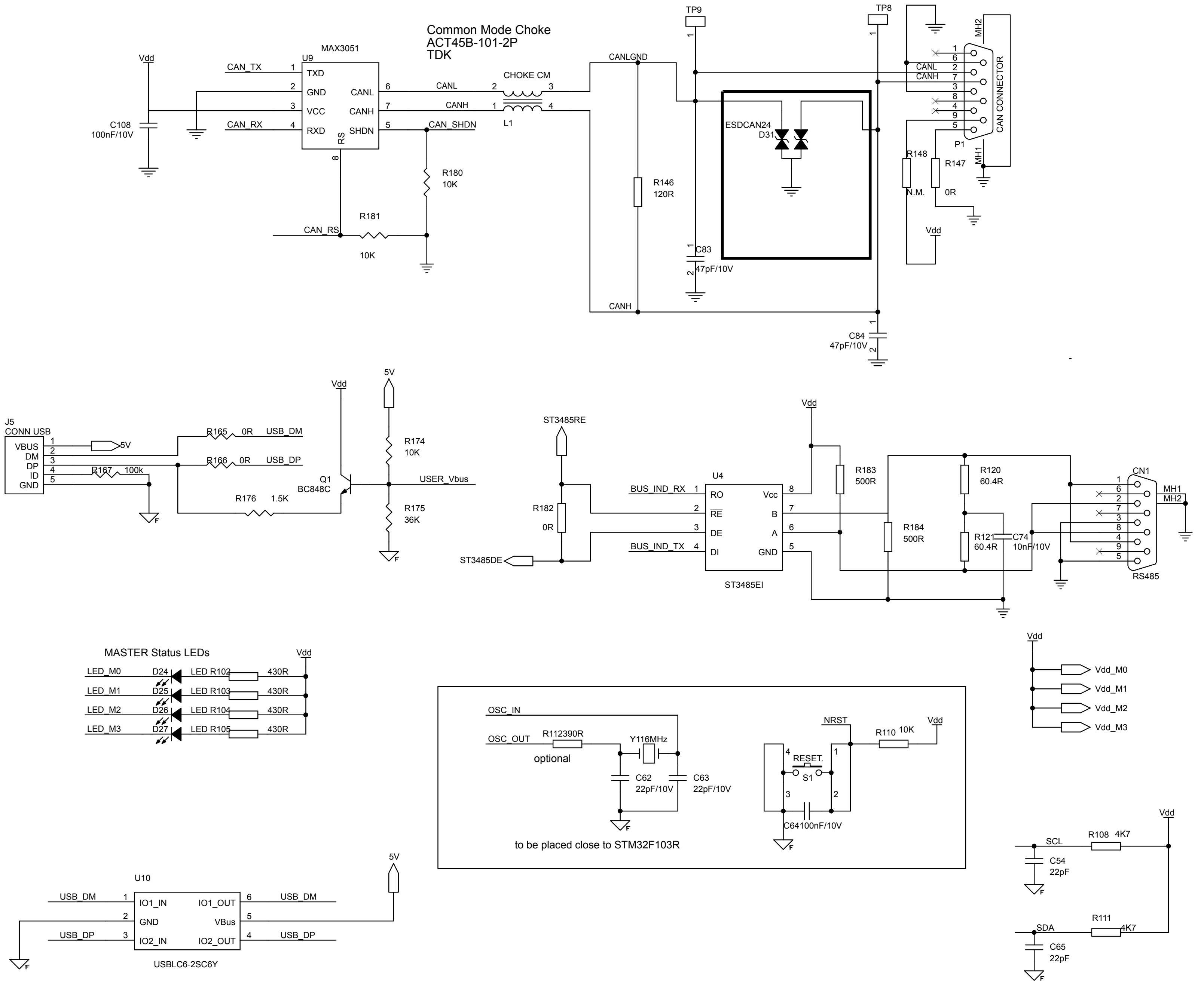


Figure 49. STEVAL-IDP004V2 circuit schematic (11 of 11)



9 STEVAL-IDP004V2 bill of materials

Table 5. STEVAL-IDP004V2 bill of materials

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
1	1	CN1	RS485 TH	DB9 female connector	Any	Any
2	1	CON1	Main voltage TH	Two-way screw connector	Any	Any
3	1	J4	TH	20-way male IDC connector	Any	Any
4	4	C1, C3, C19, C21	10 µF 50 V ±20% TH	Electrolitic capacitor	Rubycon	50YXF10MEFC5X11
5	24	C2, C4, C9, C10, C13, C14,C16, C18, C20, C22, C27, C28, C31, C32, C33, C36, C64, C68, C69, C70, C71, C72, C73, C108	100 nF 50 V ±5% SMD 0603 X7R	Ceramic capacitor	Murata	GRM188R71H104JA93D
6	8	C5, C6, C7, C8, C23, C24, C25, C26	560 pF 50 V ±5% SMD 0603 C0G	Ceramic Capacitor	Murata	GRM1885C1H561JA01D
7	6	C12, C17, C30, C35, C66, C67	2.2 µF 10 V ±10% SMD 0805 X7R	Ceramic Capacitor	Any	Any
8	2	C37, C38	4.7 nF 4 kV TH	Single layer ceramic capacitor (not mounted)	Vishay / BC Components	VY1472M63Y5UQ63V0
9	20	C54, C62, C63, C65, C92, C93, C94, C95, C96, C97, C98, C99, C100, C101, C102, C103, C104, C105, C106, C107	22 pF 50 V ±5% SMD 0603 C0G	Ceramic capacitor	Any	Any
10	1	C74	10 nF 10 V ±10% SMD 0603 X7R	Ceramic capacitor	Any	Any
11	1	C75	2.2 µF 50 V ±10% SMD 1206 X7R	Ceramic capacitor	Any	Any
12	1	C76	82 pF 25 V ±5% SMD 0805 C0G	Ceramic capacitor	Any	Any
13	1	C77	18 nF 16 V ±10% SMD 0603 X7R	Ceramic capacitor	Any	Any
14	1	C78	22 nF 16 V ±10% SMD 0603 X7R	Ceramic capacitor	Any	Any
15	1	C79	15 µF 16 V ±20% SMD 1210 X7R	Ceramic capacitor	Any	Any
16	1	C80	220 nF 50 V ±10% SMD 0603 C0G	Ceramic capacitor	Any	Any
17	2	C83, C84	47 pF 25 V ±5% SMD 0603	Ceramic capacitor	Any	Any
18	1	C90	1 µF 10 V ±10% SMD 0603	Ceramic capacitor	Any	Any
19	1	C91	4.7 µF 10 V ±10% SMD 0805	Ceramic capacitor	Any	Any

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
20	4	DR1, DR2, DR3, DR4	VFQFPN-26L 3.5 x 5 x 1 mm	IO-Link communication master transceiver IC	ST	L6360
21	16	D9, D10, D11, D12, D13, D14, D15, D16, D17, D18, D19, D20, D24, D25, D26, D27	LED SMD 0603	Green LED	Any	Any
22	1	D21	SMC	Transil Diode 1500 W	ST	SM15T33CA
23	1	D28	SMA	High voltage Power Schottky rectifier	ST	STPS1H100A
24	1	D29	SMA	Low drop Power Schottky rectifier	ST	STPS1L40A
25	1	D31	ESDCAN24 SOT23-3L	Automotive dual-line Transil, transient voltage suppressor (TVS) for CAN bus	ST	ESDCAN24-2BLY
26	8	D1, D2, D3, D4, D5, D6, D7, D8	STPS1L40M Stmite	Low drop Power Schottky rectifier	ST	STPS1L40M
27	4	JR1, JR2, JR3, JR4	Master TH	M12, 5 pin female connector, right angle	Norcomp Inc.	861-005-213R004
28	1	J5	CONN USB Micro-USB A/B	USB connector	Molex	475900001
29	1	L1	CHOKE CM	Choke	TDK	ACT45B-101-2P-TL003
30	1	L4	1.2mH 1 Ohm TH	Inductor	Wurth Elektronik	7447480122
31	1	P1	CAN connector TH	DB9 male connector	Any	Any
32	1	Q1	BC848C SOT-23	NPN transistor	Infineon	BC848C
33	36	R1, R2, R3, R5, R9, R10, R11, R12, R13, R14, R15, R16, R17, R18, R19, R20, R22, R24, R25, R26, R28, R29, R33, R34, R35, R36, R37, R38, R39, R40, R41, R42, R43, R45, R47, R48	150 R SMD 0603 100 mW	Resistors	Any	Any
34	46	R4, R7, R27, R30, R67, R68, R70, R72, R77, R78, R79, R80, R81, R82, R84, R86, R88, R90, R91, R92, R94, R97, R98, R106, R107, R109, R113, R118, R119, R154, R155, R156, R159, R160, R161, R162, R163, R164, R168, R169,	100 R SMD 0603 100 mW	Resistors	Any	Any

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
		R170, R171, R172, R177 ,R178, R179				
35	2	R83, R85	100R SMD 0603 100 mW	Resistors	Any	Any
36	4	R6, R8, R31, R32	15 R SMD 0805 500 mW	Resistors	Any	Any
37	4	R21, R23, R44, R46	124 K 0.1% SMD 0603 100 mW	Resistors	Any	Any
38	12	R49, R50, R51, R52, R53, R54, R55, R56, R57, R58, R59, R60	680 R SMD 0603 100 mW	Resistors	Any	Any
39	4	R102, R103, R104, R105	430 R SMD 0603 100 mW	Resistors	Any	Any
40	3	R108, R111, R124	4 K7 SMD 0603 100 mW	Resistors	Any	Any
41	5	R110, R173, R174, R180, R181	10 k SMD 0603	Resistors	Any	Any
42	1	R125	11 K SMD 0603 100 mW	Resistors	Any	Any
43	1	R112	390 R SMD 0603 100 mW	Resistors	Any	Any
44	4	R114, R115, R116, R117	1 R SMD 0603 100 mW	Resistors	Any	Any
45	2	R120, R121	60.4 R SMD 0603 100 mW	Resistors	Any	Any
46	1	R126	383 R SMD 0603 100 mW	Resistors	Any	Any
47	5	R127, R147, R165, R166, R182	0 R SMD 0603 100 mW	Resistors	Any	Any
48	1	R128	0 R SMD 0603 100 mW	Resistor (not mounted)	Any	Any
49	1	R146	120 R SMD 0603 100 mW	Resistor	Any	Any
50	1	R148	SMD 0603 100 mW	Resistor (not mounted)	Any	Any
51	1	R153	43 R SMD 0603 100 mW	Resistor	Any	Any
52	1	R167	100 K SMD 0603 100 mW	Resistor	Any	Any
53	1	R175	36 K SMD 0603 100 mW	Resistor	Any	Any
54	1	R176	1.5 K SMD 0603 100 mW	Resistor	Any	Any
55	2	R183, R184	500 R SMD 0603 100 mW	Resistors	Any	Any
56	1	S1	RESET SMD	MICRO SWITCH 6x6mm	TE Connectivity	4-1437565-1
57	3	TP1, TP8, TP9	TEST POINT	Copper area test point (not mounted)	Any	Any
58	4	TR1, TR2, TR3, TR4	SPT01-335DEE QFN 3x3 6+3 lead	Automation sensor transient and overvoltage protection	ST	SPT01-335DEE
59	1	U1	L7986A HSOP8	3 A step-down switching regulator	ST	L7986A

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
60	1	U4	ST3485EI SO-8	3.3 V powered, 15 kV ESD protected, up to 12 Mbps RS-485/RS-422 transceiver	ST	ST3485EIDT
61	1	U7	STM32F205RBT7 LQFP64	High-performance ARM Cortex-M3 MCU with 128 Kbytes Flash	ST	STM32F205RBT7
62	1	U9	MAX3051 SO8	CAN transceiver	Maxim	MAX3051ESA+
63	1	U10	USBLC6-2SC6Y SOT23-6L	Automotive very low capacitance ESD protection	ST	USBLC6-2SC6Y
64	1	Y1	16 MHz SMD	Crystal oscillator	Any	Any

Revision history

Table 6. **Document revision history**

Date	Version	Changes
05-Oct-2017	1	Initial release.
06-Jun-2018	2	Updated Section 6 STEVAL-IDP003V1 bill of materials, Figure 5. STEVAL-IDP004V1D power management schematic, Figure 6. RS-485, USB and CAN interface, Section 7 STEVAL-IDP004V1 schematic diagrams, Section 8 STEVAL-IDP004V1 bill of materials, Figure 18. STEVAL-IDP004V1 evaluation firmware project related to RS-485 implementation, Figure 22. Master Node folder with STEVAL-IDP004V1.hex, Figure 23. Sensor folder with STEVAL-IDP003V1.hex, Figure 24. COM port connection with Tera Term, Figure 25. COM port settings, Figure 26. Terminal settings and Figure 28. STEVAL-IDP004V1 - STEVAL-IDP003V1 communication example.
27-Jun-2018	3	Updated Figure 1. STEVAL-IDP004V1 master evaluation board and Figure 3. STEVAL-IDP004V1 functional blocks.
02-Dec-2019	4	Updated title, Introduction, Section 1.1 STEVAL-IDP004V2 master hub overview, Section 1.2.1 STEVAL-IDP003V1D evaluation board, Section 3 Firmware description and Figure 18. STEVAL-IDP004V2 evaluation firmware project related to RS-485 implementation. Added Section 3.1 STSW-IO-LINK firmware package description, Section 3.2 Firmware package with IO-Link stack implementation, Section 3.2.1 Firmware package for STEVAL-IDP004V2, Section 3.2.2 Firmware package for STEVAL-IDP003V1, Section 5 Functionality test with IO-Link stack, Section 5.1 Microcontroller programming procedure, Section 5.2 How to use TEConcept Control Tool, Section 8 STEVAL-IDP004V2 schematic diagrams and Section 9 STEVAL-IDP004V2 bill of materials.
01-Oct-2020	5	Updated Section 3.2.2 Firmware package for STEVAL-IDP003V1.
08-Apr-2025	6	Updated Introduction.

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