UM2304

User manual

Insulated AC switch control evaluation board for home appliances

Introduction

The STEVAL-GLA001V1 evaluation board is designed to help you develop applications with insulated control of three AC loads up to 1 kW (230 Vrms) using Triacs and AC switches instead of relays.

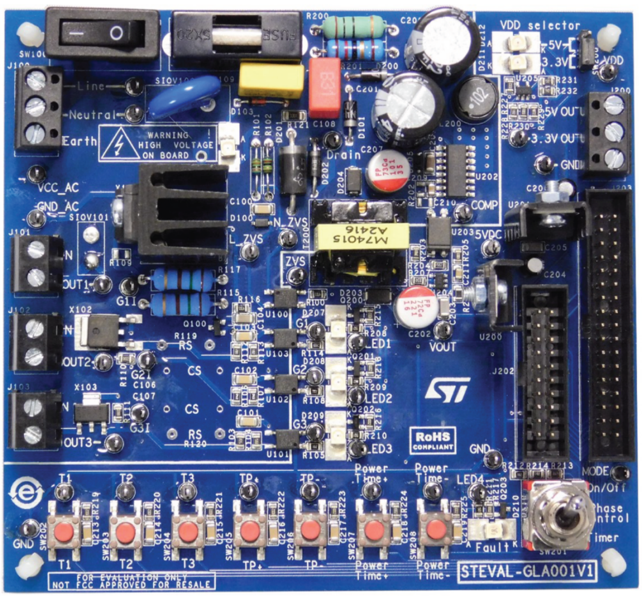
To control the STEVAL-GLA001V1 evaluation board, you can use a NUCLEO-F030R8 development board which allows three AC switch control modes for load control: continuous or pulse gate current, a timer option, and phase control. You can use also any external microcontroller.

Once you have installed the relevant firmware (available free on the STSW-GLA001V1 web page) on the NUCLEO-F030R8 development board, you can start adjusting the main parameters through a common serial interface like HyperTerminal.

The STEVAL-GLA001V1 evaluation board features a wide input voltage range, low standby power losses, IEC61000-4-4 robustness and two low voltage power supplies.

The targeted applications are residential appliances requiring insulation between microcontroller and mains voltage, such as washing machines and dish washers, micro-wave ovens, cookers, ovens, soya-milk makers, printers, air-conditioners, fridges, water-heaters and heaters.

Figure 1. STEVAL-GLA001V1 evaluation board (top view)



1 Evaluation board objectives

1.1 What does this evaluation board aim to demonstrate

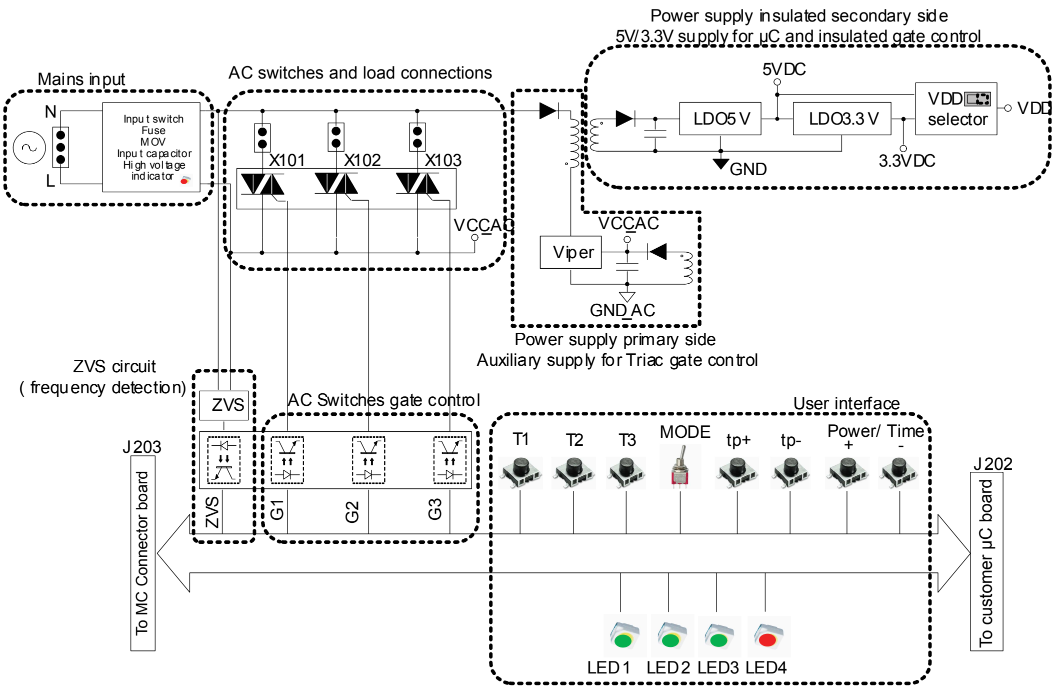
As said in the introduction, this board allows insulated control of AC loads using AC switches instead of relays solution. This board embeds a power supply which makes the board independent from power side. User has just to connect mains voltage, loads and an external microcontroller. On the smart control side, using a Nucleo board with the available firmware allows to easily configure a lot of parameters for specific loads control.

1.2 STEVAL-GLA001V1 evaluation board main blocks

The STEVAL-GLA001V1 evaluation board features the following main components:

- AC switches (X101, X102 and X103)
- A flyback power converter providing:
  - VCC_AC: non regulated output and referenced to mains voltage (VCC_AC positive regarding GND_AC).
    - used to control the three AC switches.
    - maximum output current: 150 mA
  - 5VDC: 5 V positive output, referenced to GND, insulated regarding mains voltage.
    - supplies the LEDs and all other electronic parts if VDD selector is set to 5V position
    - maximum output current: **500 mA for all the secondary side (5 V, 3.3 V and VDD mixed)**
  - 3.3VDC: 3.3 V positive output, referenced to GND, insulated regarding mains voltage.
    - supplies all other electronic parts if VDD selector is set to 3.3 V position.
    - maximum output current: **500 mA for all the secondary side (5 V, 3.3 V and VDD mixed)**
  - VDD: used to select whether the external microcontroller is supplied with 5 V or 3.3 V (default).

Figure 2. STEVAL-GLA001V1 evaluation board synoptic



1.3 Targeted applications

The main targeted applications are residential appliances where insulation between microcontroller and mains voltage is required. Such applications are for example:

- Washing machine, dish washer
- Micro-wave oven, cooker, oven, soya-milk maker
- Printer
- Air-conditioning, fridge
- Water-heater, heater

1.4 Main used part-numbers

The main part-numbers references used in this evaluation board are:

- AC Switches: T1635T-8FP, ACST310-8B and ACS108-8TN
- Rectifier diodes: STPS1L60, STTH1R06 and STPS2H100
- Transil: 1.5KE220A
- Voltage regulator: LF50ABV and LF33ABV
- Flyback IC : VIPER16HD
- Voltage reference: TS431AILT
- Op-Amp: TSV631ILT

1.5 Operating range

The STEVAL-GLA001V1 evaluation board is designed to operate within the following operating conditions:

- RMS line voltage range: 90 V to 265 Vrms
- Line voltage frequency range: 50 to 60 Hz

- Ambient temperature range: 0 to 60°C
- Maximum input current: 10 Arms

1.6 Performance

The STEVAL-GLA001V1 evaluation board performance characteristics include:

- Stand-by losses < 300 mW (@ 240 V)
- IEC 61000-4-4 (STEVAL-GLA001V1 evaluation board with NUCLEO-F030R8 development board):
  - 2 kV criteria A
  - 4 kV criteria B

1.7 AC switch load capability

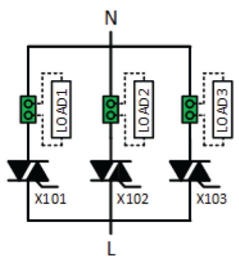
The STEVAL-GLA001V1 evaluation board is designed to operate with the following load conditions:

Table 1. Load capability versus ambient temperature and AC switch

Ambient temperature	0 °C	25 °C	60 °C
Load 1	7.2 A = 1650 W	6.2 A = 1430 W	4.6 A = 1050 W
Load 2	1.5 A = 350 W	1.3 A = 300 W	0.9 A = 205 W
Load 3	0.9 A = 200 W	0.75 A = 170 W	0.5 A = 115 W
Total loads power	2200 W	1900 W	1370 W

All of the above values are RMS, for V_{MAINS} = 230 V_{RMS} and with 5% tolerance on the maximum allowed AC switch junction temperature.
Load numbers are given with reference to the following figure.

Figure 3. Loads connection versus AC switches



2 Getting started

2.1 Safety instructions

Caution:
The high voltage levels used to operate the STEVAL-GLA001V1 evaluation board present a serious electrical shock hazard. This evaluation board must be used in a suitable laboratory by qualified personnel who are familiar with the installation, use and maintenance of power electrical systems.

The STEVAL-GLA001V1 evaluation board is designed for demonstration purposes only, and shall not be used either for domestic or industrial installations.

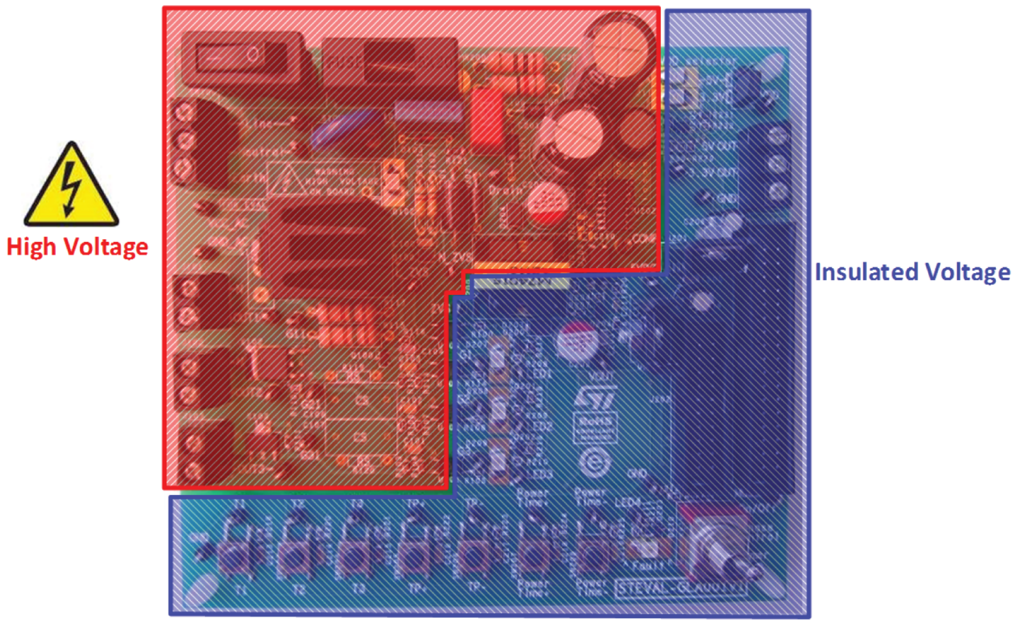
2.2 STEVAL-GLA001V1 evaluation board insulation

The STEVAL-GLA001V1 evaluation board is composed of the following main functional blocks:

- The primary side: includes mains voltage input, AC switches, power supply input, ZVS input and referenced to mains voltage
- The secondary side: includes all microcontroller input/output, power supply output, ZVS output, AC switch gate control and insulated with respect to mains voltage

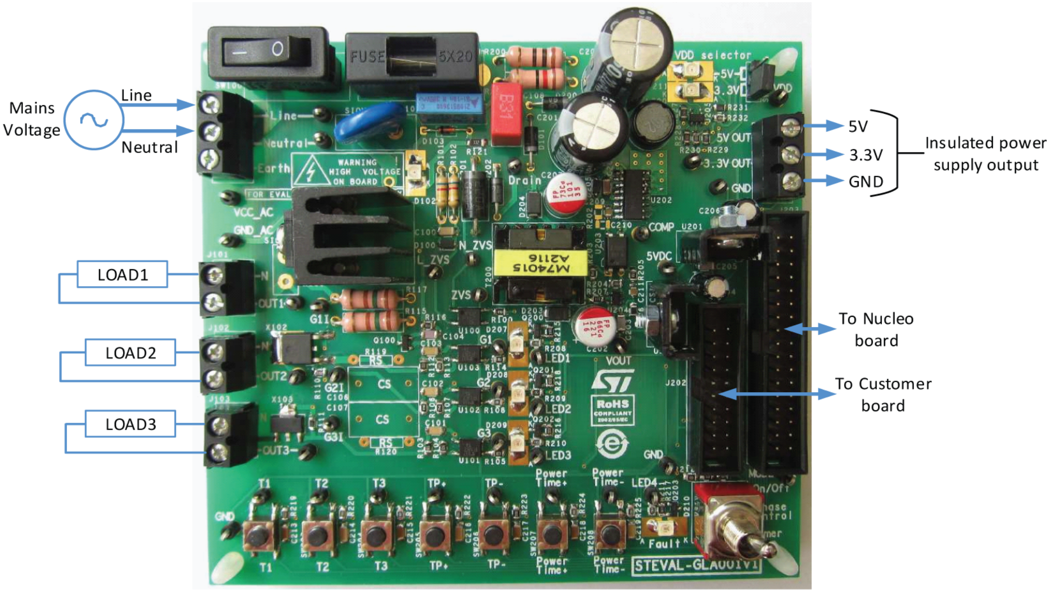
Caution:
Use insulated measuring equipment and never create a connection between high voltage and insulated voltage

Figure 4. **High voltage and insulated voltage on STEVAL-GLA001V1 evaluation board**



2.3 Board connection

Figure 5. STEVAL-GLA001V1 evaluation board connections



- J100: connect mains voltage input, complying with Line and Neutral connection and operating voltage (refer toSection 1.5 Operating range)
- J101, J102 and J103: connect directly the load between the two points, complying with the load capability (refer to Section 1.7 AC switch load capability).(1)
- J203: connect to the NUCLEO-F030R8 via the supplied ribbon cable.
- J202: connect to external microcontroller (if you don't use the NUCLEO-F030R8) with 5 V and 3.3 V, complying with power supply output capability (refer to Section 1.2 STEVAL-GLA001V1 evaluation board main blocks).
- J200: supplies insulated low voltage 5 V and 3.3 V power (if required), complying with power supply output capability (refer toSection 1.2 STEVAL-GLA001V1 evaluation board main blocks).

1. *Caution: Do not connect mains voltage*

2.4 STEVAL-GLA001V1 evaluation board start-up

Follow this procedure below to start the STEVAL-GLA001V1 evaluation board.

Step 1. Ensure SW100 switch is in the OFF position.

Step 2. Set the SW200 jumper:
- to 3.3 V for NUCLEO-F030R8 development board or 3.3 V external microcontroller
- to 5 V for 5 V external microcontroller

Figure 6. SW200 jumper

Step 3. Connect the ribbon cable between:
- J203 and the NUCLEO-F030R8 development board
- J202 and a board that is not a NUCLEO-F030R8 development board

Step 4. Connect mains voltage on J100

Step 5. Connect loads on J101 to J103

Step 6. Make sure there is no connection between high voltage and insulated voltage sections

Step 7. Ensure any measurement equipment has insulated probes

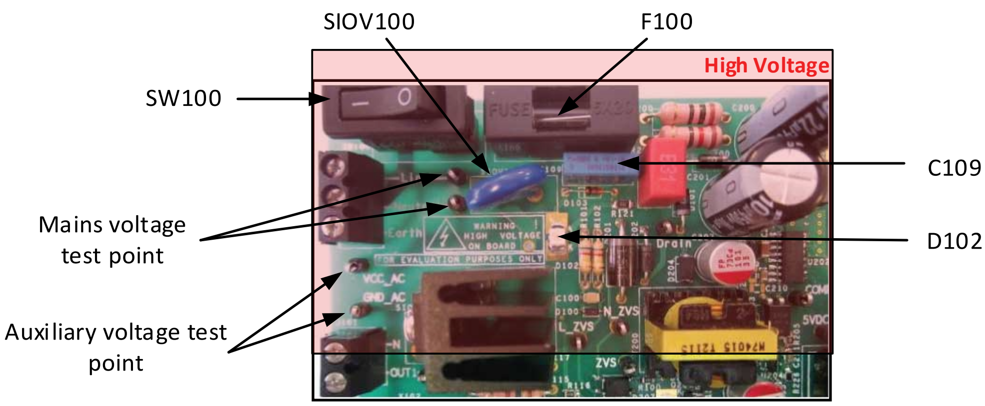
Step 8. Switch SW100 On to turn on the board

2.5 Hardware function descriptions

2.5.1 Power supply: primary side

The power supply primary side includes the following components:
- SW100 switch to turn the STEVAL-GLA001V1 evaluation board on or off
- F100 fuse and SIOV100 varistor for board protection
- C109 capacitor for noise immunity
- D102 LED for high voltage presence indication

Figure 7. STEVAL-GLA001V1 evaluation board power supply primary side components



“Line” and “Neutral” test points are available to measure mains voltage. An auxiliary power supply is generated to supply the AC switch gate control. This power supply is not regulated (fluctuates from ~12 V to ~23 V) and referenced with respect to Line potential. Up to 150 mA can be sunk from this power supply for gate control. “VCC_AC” and “GND_AC” test points are available to measure the power supply voltage level.

2.5.2 Power supply: secondary side

The power supply secondary side is represented by all the low power output insulated from mains voltage. The transformer output provides 5 V regulated voltage thanks to an LDO regulator. A 3.3 V regulated voltage is generated from the 5 V voltage thanks to a second LDO regulator.

Figure 8. **STEVAL-GLA001V1 evaluation board power supply secondary side components**

Up to 500 mA can be sunk from the secondary side in all, as the 5 V and 3.3 V voltages are in serial.

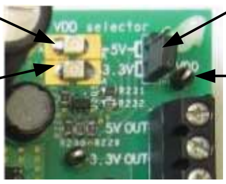
The J200 connector can supply another board or other external electronic functions. In this case, you must ensure that the sum of all current on the secondary side does not exceed the output current capability.

“5VDC”, “3.3V OUT” and “GND” test points are available to measure these two low voltages.

2.5.3 VDD selector

Some of the signals (push button, mode switch and ZVS) connected to the STM32 32-bit ARM Cortex MCU or other microcontroller input are referenced to VDD to protect the voltage input capability of any microcontroller.

Figure 9. **STEVAL-GLA001V1 evaluation board VDD selector components**



For a 3.3 V compatible microcontroller, VDD must be connected to 3.3 V by setting the SW200 jumper to the bottom (D211 LED lights up); this is the default position.

For a 5 V compatible microcontroller, VDD must be connected to 5 V by setting the SW200 jumper to the top (D212 LED lights up).

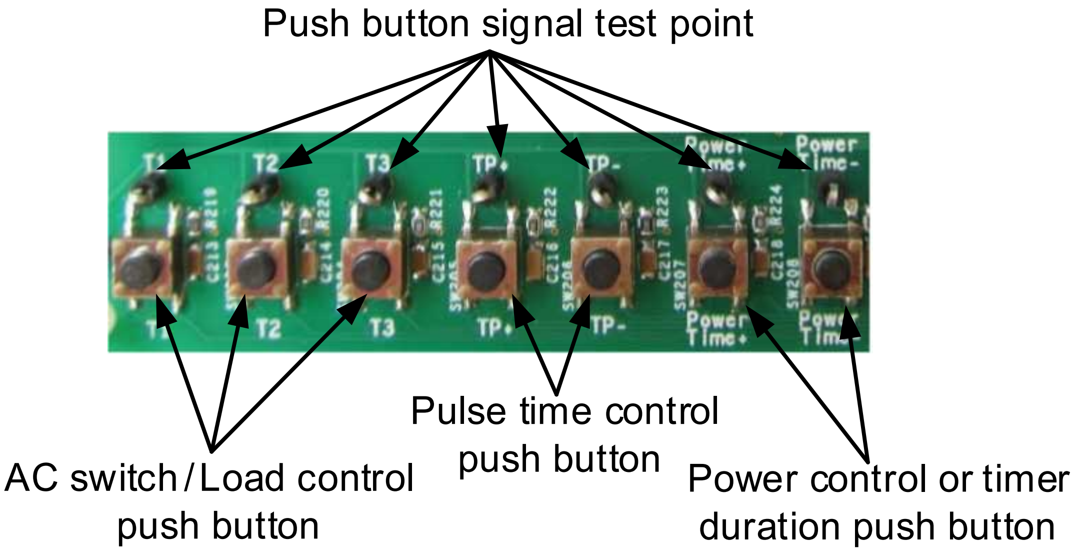
As VDD is connected to either 5 V or 3.3 V, the VDD current capability must always be taken into account in matters concerning the power supply secondary side.

“VDD” and “GND” test points are available to measure VDD voltage level.

2.5.4 Push buttons

Push button signals are available on J202 (user board) and J203 (NUCLEO-F030R8 development board) connectors. They are referenced regarding VDD and GND (refer to Section 2.5.3 VDD selector).

Figure 10. **STEVAL-GLA001V1 evaluation board push button components**



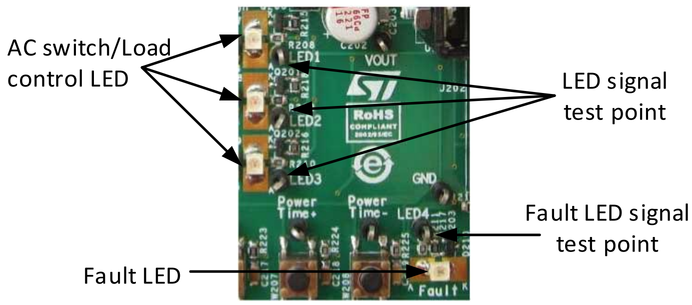
The push buttons are normally open and the signal is set to VDD. When a button is pressed, the signal is set to GND. When the button is released, the signal returns to VDD.

“T1”, “T2”, “T3”, “TP+”, “TP-”, “Power Time +”, “Power Time -” and “GND” test points are available to measure push button voltage level.

2.5.5 LEDs

LED signals are available on J202 (user board) and J203 (NUCLEO-F030R8 development board) connectors. The microcontroller voltage level is not important as they use a transistor to be voltage compatible. LED1, LED2 and LED3 are green, while the "Fault" LED4 is red.

Figure 11. **STEVAL-GLA001V1 evaluation board LED components**



If the LEDx signal is set to 0 (GND), the chosen LED is OFF; if the LEDx signal is set to 5 V, 3.3 V or VDD, the chosen LED is illuminated.

“LED1”, “LED2”, “LED3”, “LED4” and “GND” test points are available to measure led voltage level.

2.5.6 Switch mode

The mode selector switch signal is available on J202 (user board) and J203 (NUCLEO-F030R8 development board) connectors. It is referenced with respect to VDD and GND (refer to Section 2.5.3 VDD selector).

Figure 12. STEVAL-GLA001V1 evaluation board mode components

The switch has 3 ON positions, so there is a non-zero voltage on the MODE signal in any position. The following table shows MODE signal voltage with respect to the switch position.

Table 2. MODE signal voltage versus switch position

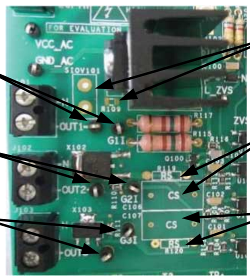
MODE switch position (board silkscreen)	MODE voltage	MODE voltage with VDD = 3.3 V	MODE voltage with VDD = 5 V
On/Off	VDD ÷ 1.62	2.04 V	3.09 V
Phase control	VDD ÷ 2.62	1.26 V	1.91 V
Timer	VDD ÷ 2	1.65 V	2.5 V

“MODE” and “GND” test points are available to measure switch mode voltage level.

2.5.7 Gate control: primary side (high voltage)

The AC switch gate control primary side contains three AC switches, the gate control circuit and optional components which can be implemented to improve AC switch performance.

Figure 13. STEVAL-GLA001V1 evaluation board AC switch gate control (primary side) components



“VCC_AC”, “GND_AC”, “OUT1”, “G1I”, “OUT2”, “G2I”, “OUT3” and “G3I” tests points are available to measure auxiliary voltage, AC switches output and gate voltage level.

Caution: All these test points are referenced to high voltage.

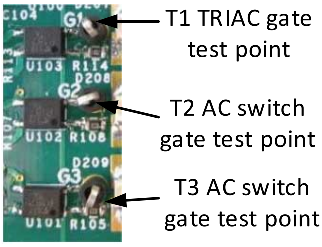
See Section 12 AC switch performance improvements for more information on how to improve AC switch performance.

2.5.8 Gate control: secondary side (insulated voltage)

The gate command signals are available on J202 (user board) and J203 (NUCLEO-F030R8 development board) connectors. The microcontroller voltage level is not important as the optocoupler LED is voltage compatible. The

G1 signal controls X101 Triac (OUT1, T1), the G2 signal controls X102 AC switch (OUT2, T2) and the G3 signal controls X103 AC switch (OUT3, T3).

Figure 14. **STEVAL-GLA001V1 evaluation board AC switch gate control (secondary side) components**



If the Gx signal is set to 0 (GND), the corresponding AC switch is turned off; if the Gx signal is set to 5 V, 3.3 V or VDD, the corresponding AC switch is switched on.

“G1”, “G2”, “G3” and “GND” test points are available to measure gate command voltage level.

2.5.9 ZVS

The ZVS (Zero Voltage Switching) signal is available on J202 (user board) and J203 (NUCLEO-F030R8 development board) connectors. It is referenced with respect to VDD and GND (refer to Section 2.5.3 VDD selector).

The ZVS signal represents the mains voltage with respect to zero crossing. It allows synchronizing AC switch control with the mains voltage frequency.

As shown on the figure below, if the mains voltage is positive (neutral with respect to line), the ZVS signal is set to GND. If the mains voltage is negative (neutral with respect to line), the ZVS signal is set to VDD.

Figure 15. **ZVS signal versus mains voltage**

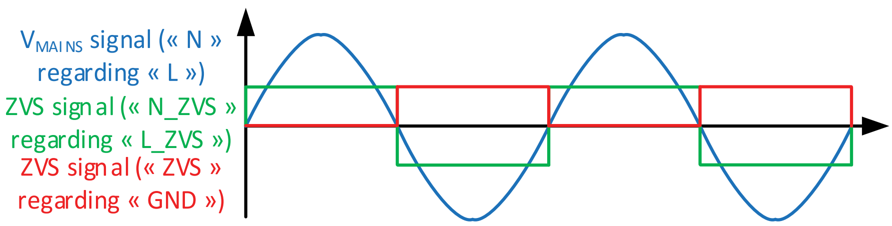
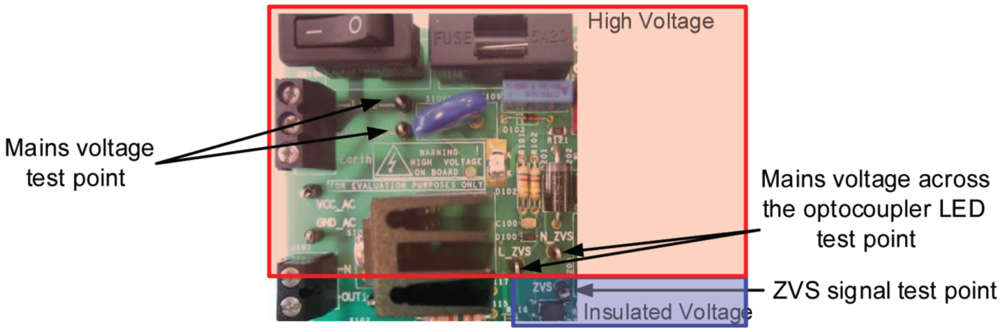


Figure 16. **STEVAL-GLA001V1 evaluation board ZVS components**



From the primary side, “Line”, “Neutral”, “N_ZVS” and “L_ZVS” test points are available to measure ZVS voltage level.

Caution: These test points are referenced to high voltage.

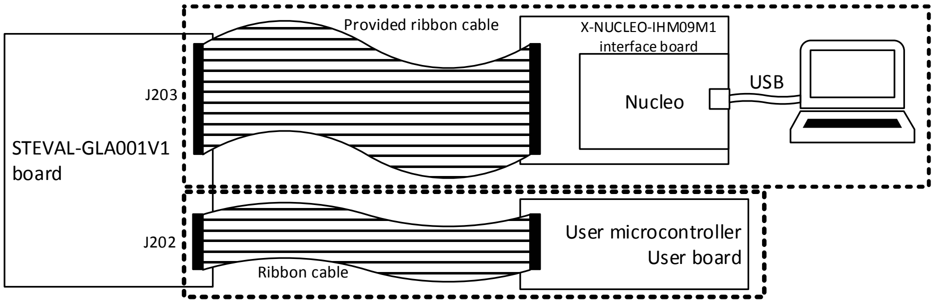
From the secondary side (low voltage and insulated), “ZVS” and “GND” test points are available to measure ZVS voltage level.

3 Evaluation board operation with Nucleo board

3.1 Overview

As shown in Figure 17. Ways to control the STEVAL-GLA001V1 evaluation board, you can either connect the STEVAL-GLA001V1 evaluation board to your own board and microcontroller, or to the X-NUCLEO-IHM09M1 interface board for STM32 Nucleo mounted on a NUCLEO-F030R8 development board, which is in turn connected to a PC via a USB cable (Type A/Mini A).

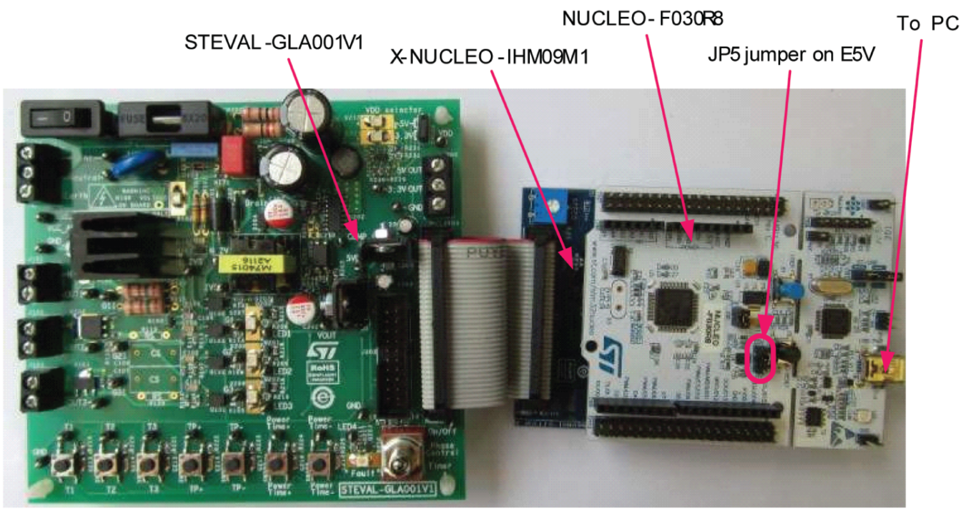
Figure 17. Ways to control the STEVAL-GLA001V1 evaluation board



To use the STEVAL-GLA001V1 evaluation board with the NUCLEO-F030R8 development board the NUCLEO-F030R8 development board must first be programmed with the firmware you can download from the STSW-GLA001V1 web page (find detailed instructions in the firmware user manual).

After programming the NUCLEO-F030R8 development board, set jumper JP5 to the E5V position.

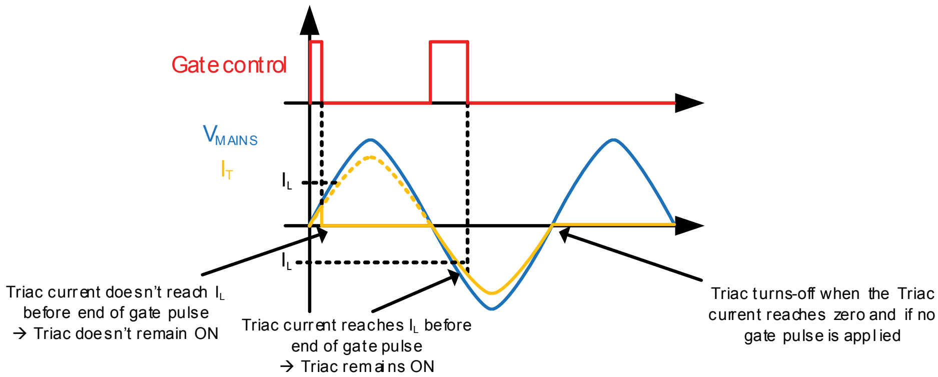
Figure 18. Connection setup between for STEVAL-GLA001V1 evaluation board, X-NUCLEO-IHM09M1 connector expansion board and NUCLEO-F030R8 development board



3.2 Triac control

A Triac or AC switch can be controlled through a DC or pulse gate command. If you apply a gate current until the Triac current exceeds I_L (latching current), the Triac remains ON even if the gate current is removed. The Triac turns OFF when the Triac current reaches zero, if the gate control is released.

Figure 19. Triac behavior according to gate control and latching current



You can control a Triac gate in one of the following ways:

1. DC gate control: a continuous gate current is applied. This ensures the TRIAC turns ON, but it is energy-consuming.
2. Pulse gate control: a pulse gate current is applied. The gate power consumption is lower but you need to verify that I_L is reached before releasing the gate current.

3.3 Operating mode

The following operating modes are available to use the loads by controlling the AC switches:

1. ON/OFF basic mode: the Triac is ON during the whole period. So the load current is a full-wave sinusoidal current. This control mode is usually used to control fans, pumps or resistive loads. The gate signal can be DC or pulsed.
2. ON/OFF timer mode: the Triac is ON for a defined period, so the load current is a full-wave sinusoidal current for a chosen duration. This control mode is usually used to control fans, pumps or resistive loads, and also for specific applications like lighting and other home control applications with timer functions.
3. Phase control mode: the Triac turns ON with a delay with respect to the ZVS. Current conduction starts at the end of the half-cycle. The current conduction per half-cycle can then be set between 0 to half-a-cycle in order to control the load power. This control mode is usually used to control fans, universal motor speeds or lamp brightness. Only the pulse gate command is available.

The above loads (and corresponding AC switches) can be controlled at the same time or individually. To control several AC switches at the same time, the control mode and parameters are common to all the AC switch controls.

3.3.1 Mode selection

The “ON/OFF basic”, “ON/OFF timer” and “Phase control” operating modes are selectable through the three-position “MODE” switch (SW201), see Section 2.5.6 Switch mode for more information.

3.3.2 ON/OFF basic mode

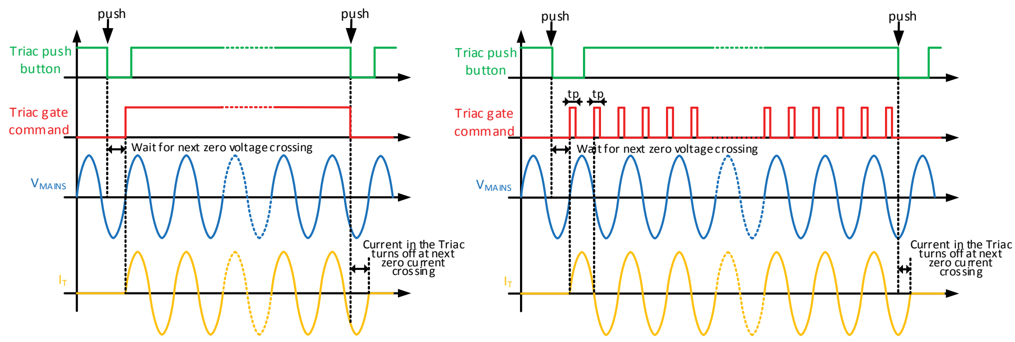


Figure 20. ON/OFF control in basic mode (DC command on the left and pulse command on the right)

This mode is selected through the MODE switch (refer to Section 3.3.1 Mode selection).

After you push the AC switch/Load button (Tx) ON, the NUCLEO-F030R8 development board waits for the next ZVS, lights ON the corresponding LED (LEDx) and then activates the corresponding AC switch gate (Gx).

To stop the AC switch/load, push the AC switch/Load button (Tx) ON again: the gate is deactivated and the LED is switched OFF.

By default, the gate command is a pulsed signal with a duration equal to the “tp” value. You can modify this gate ON duration by pushing on the “TP+” button (to increase ON time) or “TP-” button (to decrease ON time). The gate command becomes a DC signal when the “tp” value reaches the half-period.

All parameters (range, default value, unit, step, etc.) used to configure the load control for this mode are described in Section 3.6 User interface. For more details regarding the hardware components involved in this mode, refer to Section 2.5 Hardware function descriptions.

3.3.3 ON/OFF timer mode

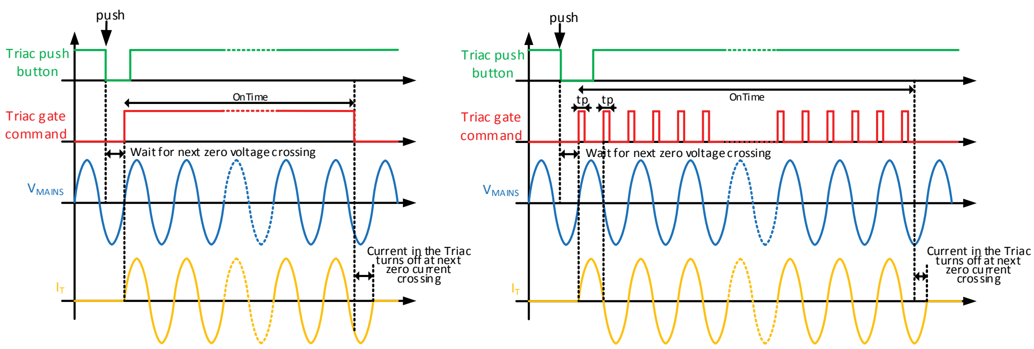


Figure 21. ON/OFF control in timer mode (DC command on the left and pulse command on the right)

This mode is selected through the MODE switch (refer to Section 3.3.1 Mode selection). This mode operation is similar to the ON/OFF basic mode, but a timer stops the AC switch/Load instead of pushing a button.

When you push the AC switch/Load button (Tx) ON, the NUCLEO-F030R8 development board waits for the next ZVS, lights ON the corresponding LED (LEDx) and then activates the corresponding AC switch gate (Gx).

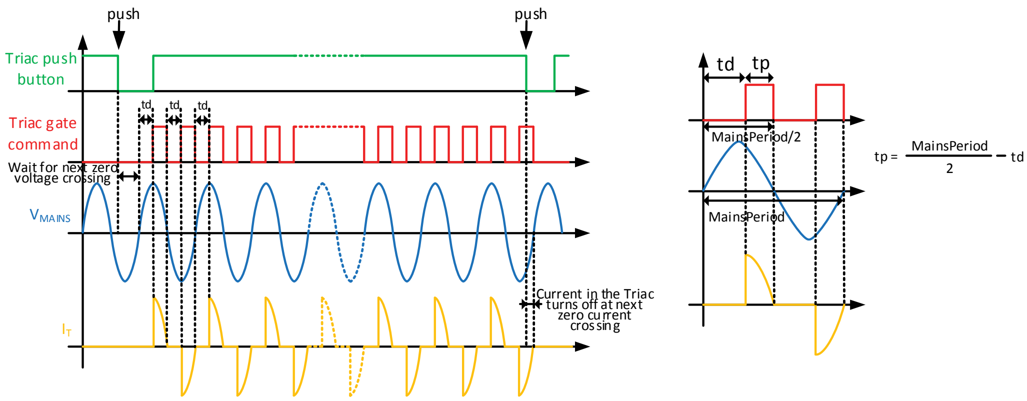
The AC switch/load is stopped after the timer (“OnTime” duration) has elapsed: the gate is deactivated and the LED is switched OFF.

By default, the gate command is a pulsed signal with a duration equal to “tp” value. You can modify this gate ON duration by pushing on the “TP+” button (to increase ON time) or “TP-” button (to decrease ON time). The gate command becomes a DC signal when “tp” value has reached the half-period. You can also modify the timer duration “OnTime” by pushing on the “Power Time +” button (to increase timer duration) or “Power Time -” button (to decrease timer duration).

All parameters (range, default value, unit, step, etc.) used to configure the load control for this mode are described in Section 3.6 User interface. For more details regarding the hardware components used for this mode, refer to Section 2.5 Hardware function descriptions.

3.3.4 Phase control mode

Figure 22. **Phase control (zoom on the right)**



This mode is selected through the MODE switch (refer to Section 3.3.1 Mode selection).

When you push the AC switch/Load button (Tx) ON, the NUCLEO-F030R8 development board waits for the next ZVS, lights ON the corresponding LED (LEDx) and then activates the corresponding AC switch gate (Gx).

The AC switch/load is stopped when the user pushes the AC switch/Load button (Tx) ON again: the gate is deactivated and the LED is switched OFF.

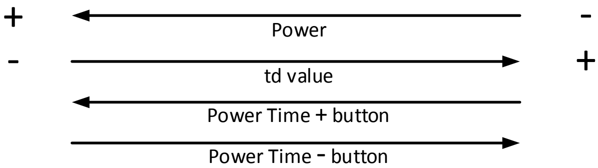
The gate command is a pulsed signal with the time delay equal to “td” value. You can modify this time delay by pushing on the “Power Time +” button (to decrease “td” and so increase load power) or “Power Time -” button (to increase “td” and so decrease load power).

“td” represents the time delay before turning on the AC switch at each cycle. The “td” value is selected from a table consisting of a configurable column number (see Figure 23. td value table details). “td” values should be entered in ascending order (lowest index for lowest “td” value and highest index for highest “td” value).

For safety reasons, on first load control with new values, the NUCLEO-F030R8 development board firmware will start with the highest “td” value (highest index), which corresponds to the minimum power.“td” is decreased (according to the table values) when “Power Time +” is pressed and increased when “Power Time -” is pressed.

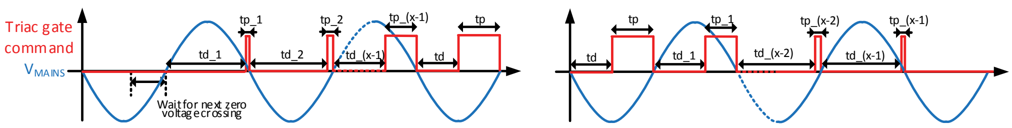
Figure 23. **td value table details**

Column number	1	2	3	4	...	N_td
td value	Value1	Value2	Value3	Value4	...	ValueN



Additionally, a soft-start and a soft-stop function are implemented in this mode to allow starting and stopping the load gradually. The number of steps is configurable.

Figure 24. **Soft-start operation (on the left) and soft-stop operation (on the right)**

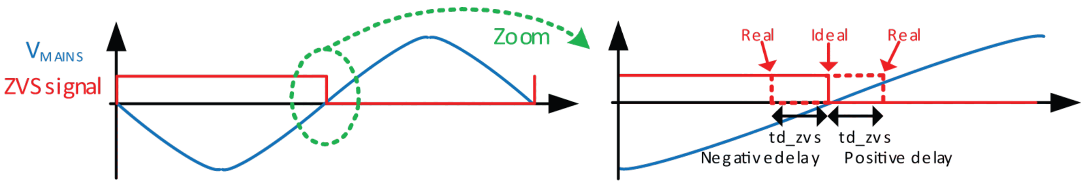


All parameters (range, default value, unit, step, etc.) used to configure the load control for this mode are described in Section 3.6 User interface. For more details regarding the hardware components used for this mode, refer to Section 2.5 Hardware function descriptions.

3.4 ZVS function

The ZVS (Zero Voltage Switching) function allows control of the loads in synchronization with the mains voltage, which is especially useful for avoiding excessive dI/dt at turn ON that can damage the AC switches. The ZVS signal versus mains voltage is shown below.

Figure 25. **ZVS signal versus mains voltage (zoom on the right)**



The real ZVS signal is not exactly synchronized with mains voltage due to component tolerance and delay. A virtual delay “td_zvs” is implemented in the NUCLEO-F030R8 development board firmware to counter this problem. You measure it with an oscilloscope and modify the value through the user interface (for more details, refer to firmware user manual).

In case of inductive load use, you must take into account the delay due to the STEVAL-GLA001V1 evaluation board and the phase shift due to the load. By adding these two delays, you can control the inductive load exactly at the zero current crossing.

Figure 26. Parameters in case of inductive load (example on the right) shows an example of inductive load use: the “Final value” entered in “td_zvs” should be the difference between the “td_zvs” delay and the inductive load delay. For example, “td_zvs” due to the STEVAL-GLA001V1 evaluation board is 1000 µs, and inductive load delay is 2500 µs: the final value is “td_zvs” – “inductive load delay” = 1000 – 2500 = –1500 µs.

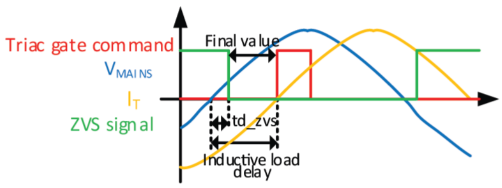


Figure 26. Parameters in case of inductive load (example on the right)

In phase control mode, the “zcs_margin” parameter lets you avoid period overlap. This parameter should be taken into account in "td" calculation: a half-period should be equal to the sum of “tp”, “td” and “zcs_margin” as shown in Figure 27. Parameters for phase control mode.

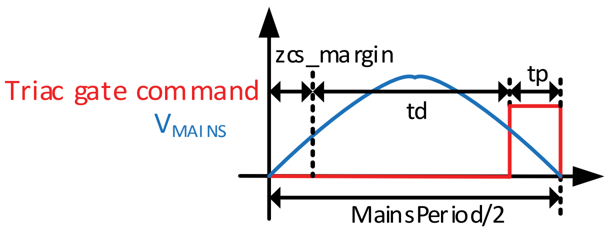


Figure 27. Parameters for phase control mode

The firmware is able to manage ZVS circuit presence: according to the “zvs_hw” parameter value, some mode operations may or may not be available. With the STEVAL-GLA001V1 evaluation board, the ZVS parameter is activated by default. In case of firmware re-use with user-own design, ZVS function could be deactivated..
Table 3. Modes and gate controls available vs zvs circuit implementation lists all load modes and gate control types available regarding ZVS circuit implementation.

Table 3. Modes and gate controls available vs zvs circuit implementation

ZVS circuit	Load control	Timer mode	Gate control
Not available	ON/OFF	No	DC
		Yes	
Available	ON/OFF	No	Pulse
			DC
		Yes	Pulse
			DC
	Phase control	Not available	Pulse

All parameters (range, default value, unit, etc.) used to configure the ZVS delay are described in Section 3.6 User interface. For more details regarding the hardware components used for this function, refer to Section 2.5 Hardware function descriptions.

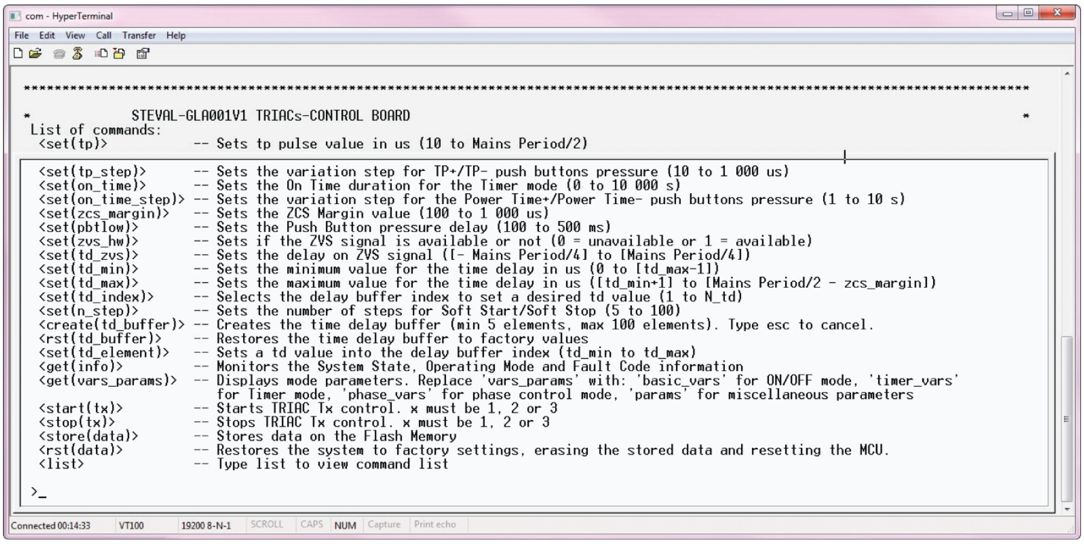
3.5 Fault LED

The red fault LED lights ON to indicate an error. Your can determine the fault type through the user interface (for more details, refer to firmware user manual). For more details regarding the hardware components used for this function, refer to Section 2.5 Hardware function descriptions.

3.6 User interface

The user-friendly interface is designed to let you read and write parameters easily. This interface consists of many commands (described in a menu) available through a terminal emulator such as HyperTerminal or TeraTerm. The list of commands is shown below.

Figure 28. **User interface list of commands**



The commands perform the following functions:

- read board state and configuration parameters
- set configuration parameters
- start and stop AC switches
- store configurations
- restore configuration to factory settings

For more details about terminal configuration and use, refer to the firmware user manual.

All the parameters in the following table are readable.

Table 4. **Readable parameters**

Name	Description	Unit
Mains period	Mains voltage period	ms
ZVS_hw	ZVS function implemented	NA
Operating mode	Operating mode selected (SW201 switch position)	NA
td_ZVS	ZVS delay	µs
PBTlow	Push button pressure delay	ms
Tx	AC switch / Load state	NA
LEDx	LED state	NA
tp	Gate control pulse time (for ON/OFF basic and timer modes)	µs
tp_step	Step for increasing or decreasing tp	µs
td	Current gate control turn-on delay (for phase control mode)	µs

Name	Description	Unit
td_buffer	td table	NA
Index	Current td table index	NA
N_td	td table columns number	NA
td_min	Minimum of td value range	µs
td_max	Maximum of td value range	µs
Soft Start/Stop n_step	Number of steps for soft-start and soft-stop	NA
OnTime	Timer duration (for timer mode)	s
OnTime_step	Step for increasing or decreasing OnTime	s
ZCS margin	Margin before next cycle (for phase control mode)	µs
System State	State of the STEVAL board	NA
Fault Code	Information about board error	NA

All the parameters in the following table are configurable.

Table 5. Configurable parameters

Name	Description	Unit	Range	Default value	Storable
tp	Gate control pulse time (for ON/OFF basic and timer modes)	µs	10 to (Mains Period ÷ 2)	5000	Yes
tp_step	Step for increasing or decreasing tp	µs	10 to 1000	1000	Yes
on_time	Timer duration (for timer mode)	s	0 to 10 000	5	Yes
on_time_step	Step for increasing or decreasing on_time	s	1 to 10	1	Yes
zcs_margin	Margin before next cycle (for phase control mode)	µs	100 to 1000	100	Yes
pbtlow	Push button pressure delay	ms	100 to 500	100	Yes
zvs_hw	ZVS function implemented	NA	0 or 1	1	Yes
td_zvs	ZVS delay	µs	(- Mains Period ÷ 4) to (Mains Period ÷ 4)	0	Yes
td_min	Minimum td value range	µs	0 to td_max-1	0	Yes
td_max	Maximum td value range	µs	(td_min+1) to (Mains Period ÷ 2-zcs_margin)	Mains Period ÷ 2-zcs_margin	No
td_index	td table index	NA	1 to N_td	N_td	Yes
n_step	Number of steps for soft-start and soft-stop	NA	5 to 100	10	Yes
td_buffer	td table	NA	5 to 100	20	Yes
td_element	td value of chosen index	NA	td_min to td_max	NA	Yes

For more details about parameters, refer to the firmware user manual.

4 Evaluation board operation without Nucleo board

4.1 User connector inputs and outputs

If you wish to connect the STEVAL-GLA001V1 evaluation board to your own-board embedding another microcontroller, refer to the following figure and table for details regarding the signal type of each pin.

Figure 29. User connector pinning

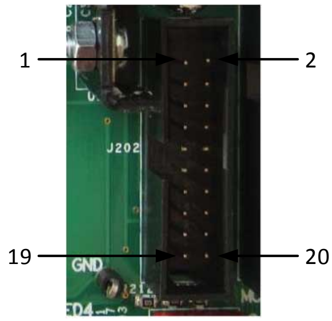


Table 6. User connector pin description

Pin N.	Name	Description	Type from user side	Voltage level
1	NC	Not connected	NA	NA
2	GND	Power supply GND (insulated from mains voltage)	Power supply	GND
3	ZVS	ZVS picture signal	Input	VDD/GND
4	G1	AC switch n°1 gate control command	Output	VDD/GND
5	LED1	LED n°1 command	Output	VDD/GND
6	G2	AC switch n°2 gate control command	Output	VDD/GND
7	T1	AC switch n°1 control push button	Input	VDD/GND
8	G3	AC switch n°3 gate control command	Output	VDD/GND
9	T3	AC switch n°3 control push button	Input	VDD/GND
10	MODE	Mode switch voltage	Input	Refer to Section 4.2 MODE switch voltage
11	T2	AC switch n°2 control push button	Input	VDD/GND
12	TP-	tp decrease push button	Input	VDD/GND
13	LED3	LED n°3 command	Output	VDD/GND
14	TP+	tp increase push button	Input	VDD/GND

Pin N.	Name	Description	Type from user side	Voltage level
15	3.3VDC	3.3 V power supply (to supply user board)	Power supply	3.3 V referenced to GND
16	LED2	LED n°2 command	Output	VDD/GND
17	5VDC	5 V power supply (to supply user board)	Power supply	5 V referenced to GND
18	Power Time +	Power or timer duration increase push button	Input	VDD/GND
19	Power Time -	Power or timer duration decrease push button	Input	VDD/GND
20	LED4	LED n°4 command	Output	VDD/GND

4.2 MODE switch voltage

MODE switch (SW201) is a three-positions switch, and each position is connected to different resistors which change voltage on the MODE signal (see Section 2.5.6 Switch mode).

5 Schematic diagrams

Figure 30. **STEVAL-GLA001V1 - AC input**

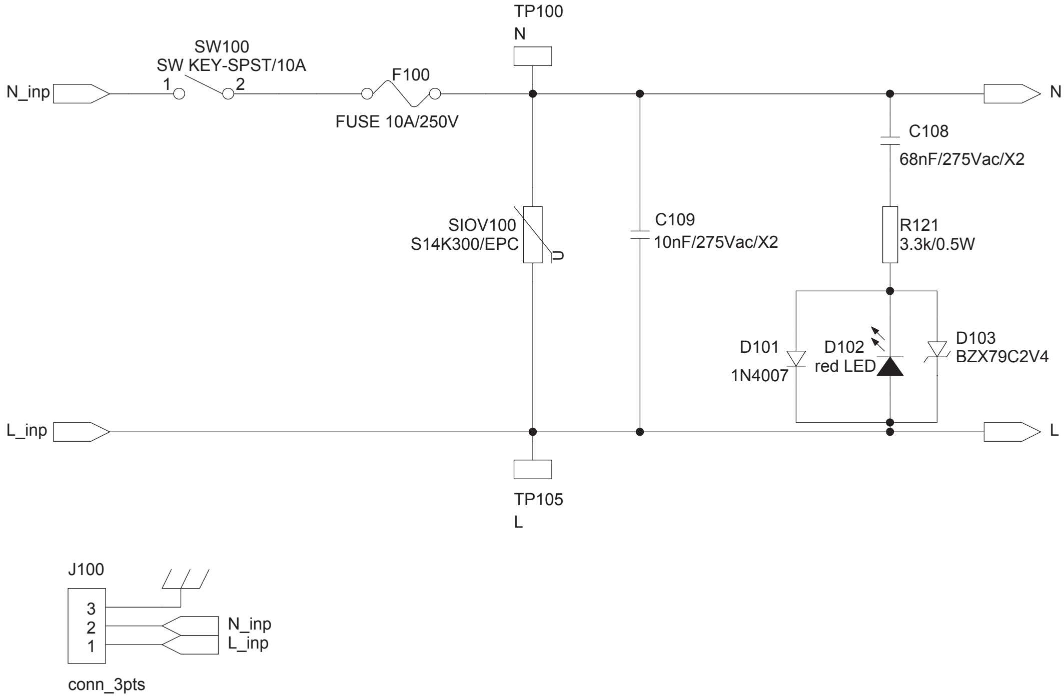


Figure 31. **STEVAL-GLA001V1 - ZVS detection**

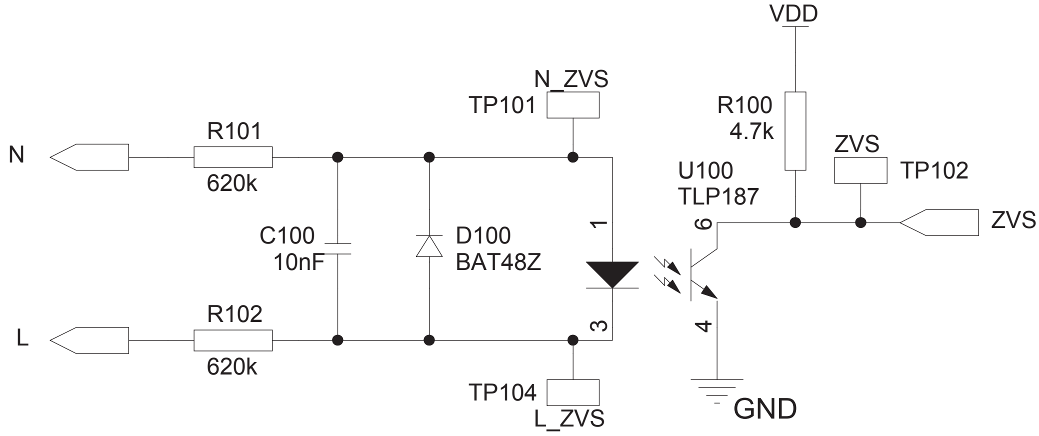


Figure 32. **STEVAL-GLA001V1 - Triac gate control**

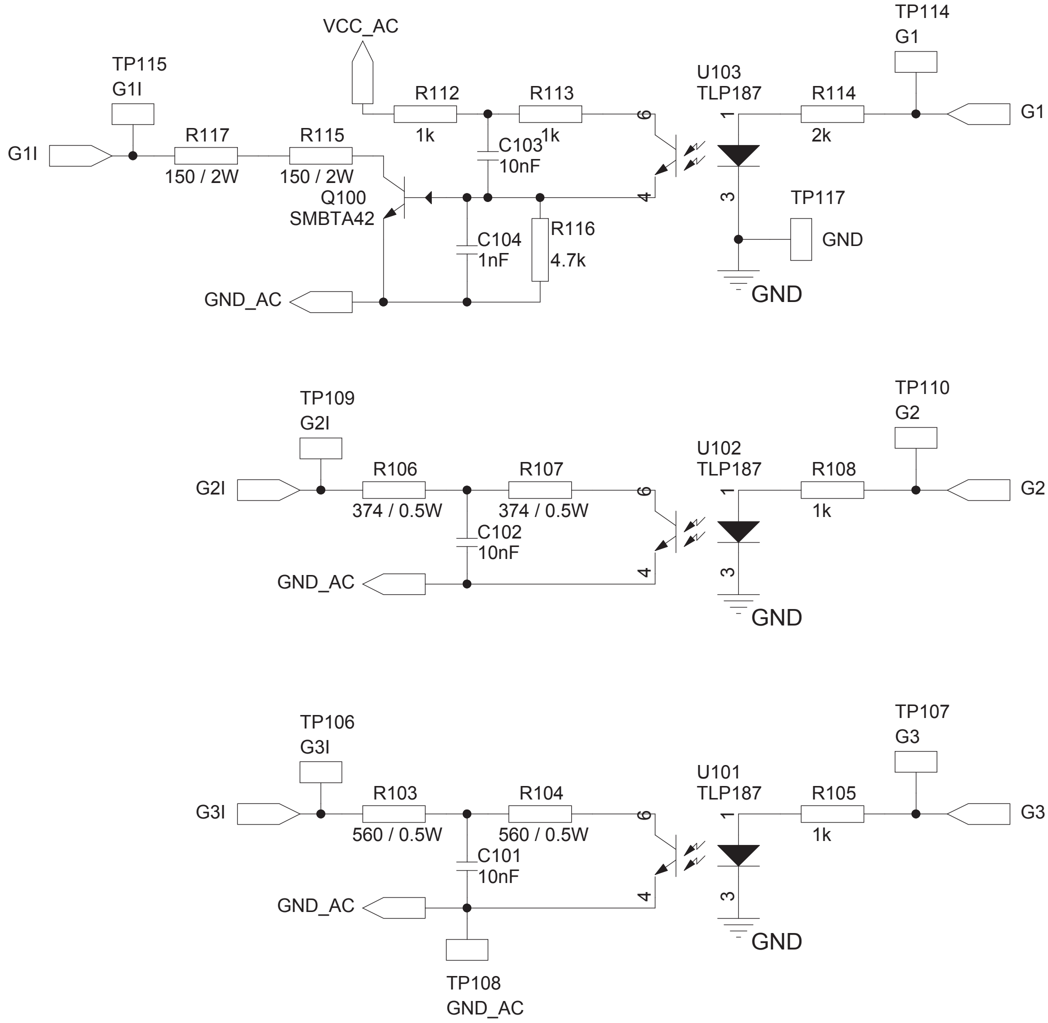


Figure 33. **STEVAL-GLA001V1 - Triacs/ACS connection**

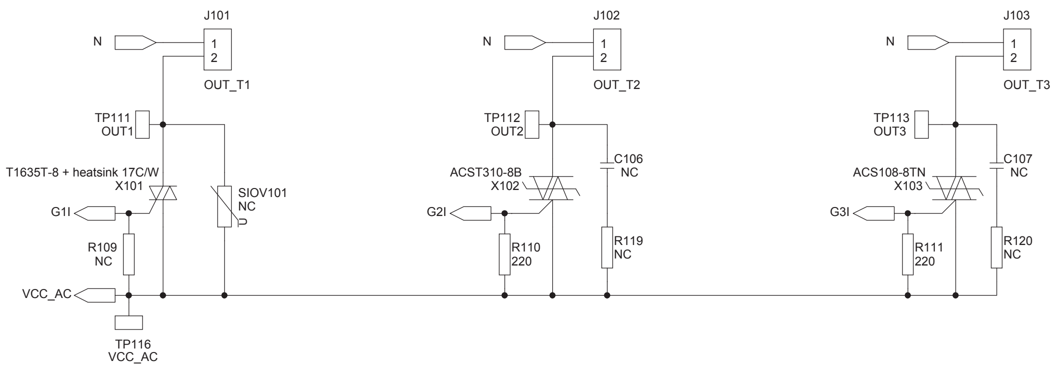


Figure 34. **STEVAL-GLA001V1 - Power supply**

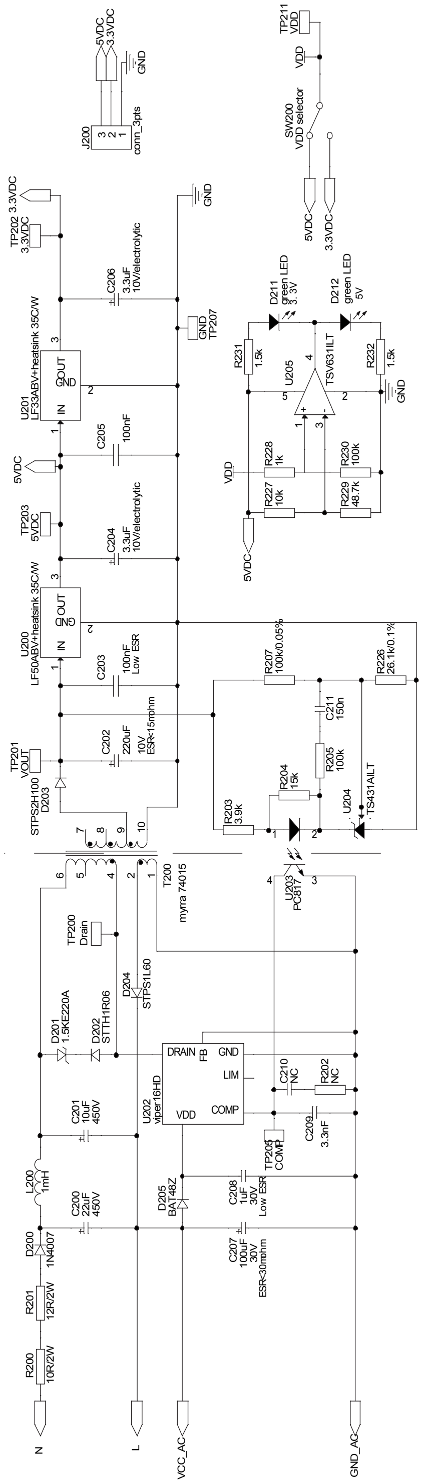


Figure 35. **STEVAL-GLA001V1 - LED indicators**

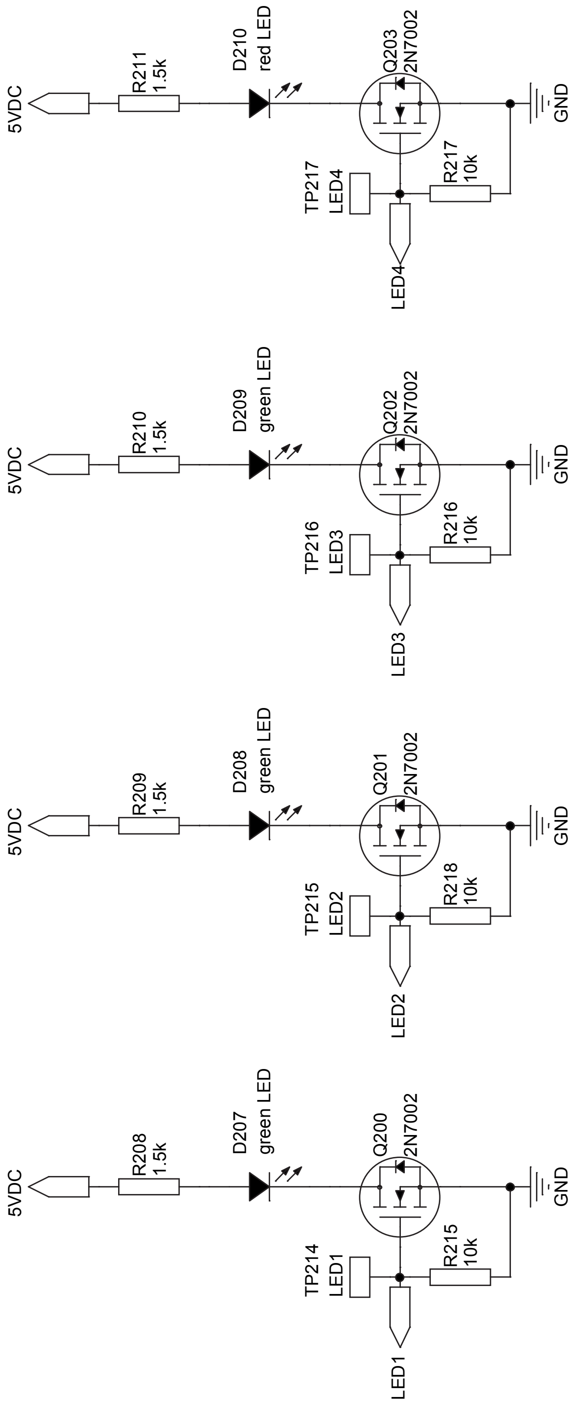


Figure 36. **STEVAL-GLA001V1 - Commands/parameters push buttons**

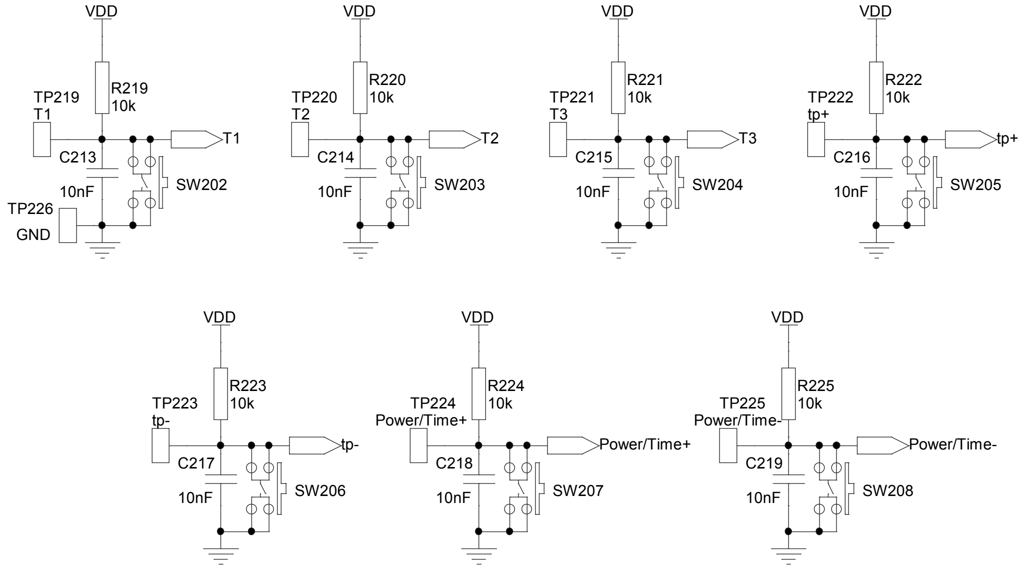


Figure 37. **STEVAL-GLA001V1 - Mode selector switch**

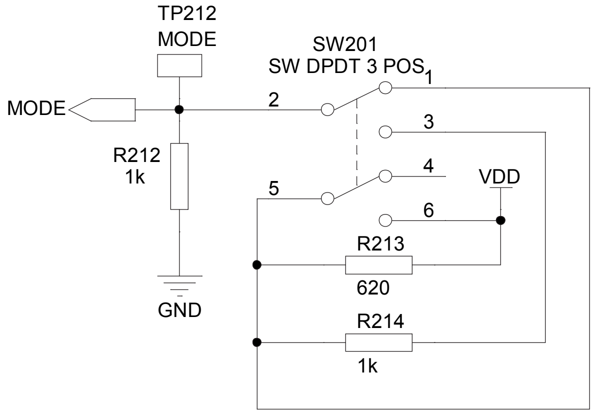


Figure 38. **STEVAL-GLA001V1 - Customer board connector**

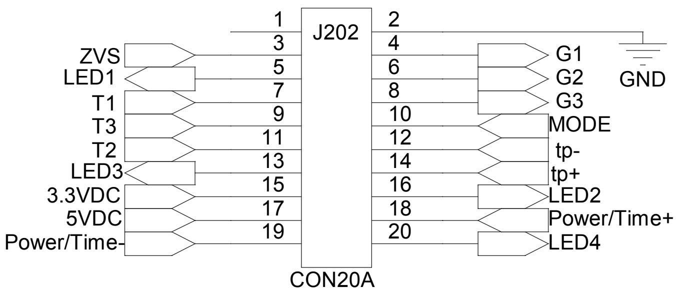
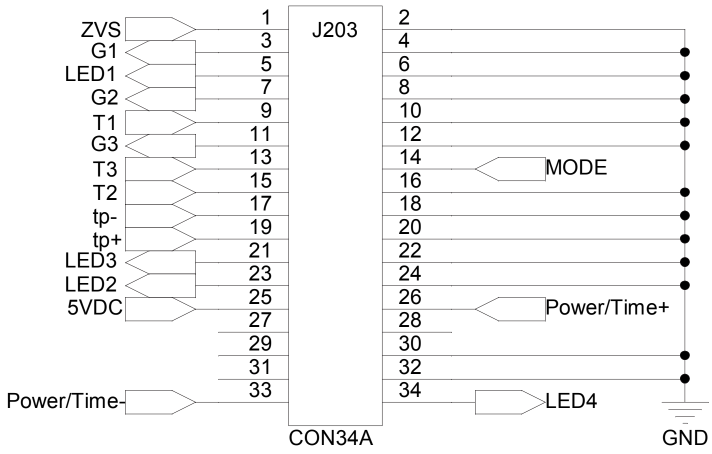
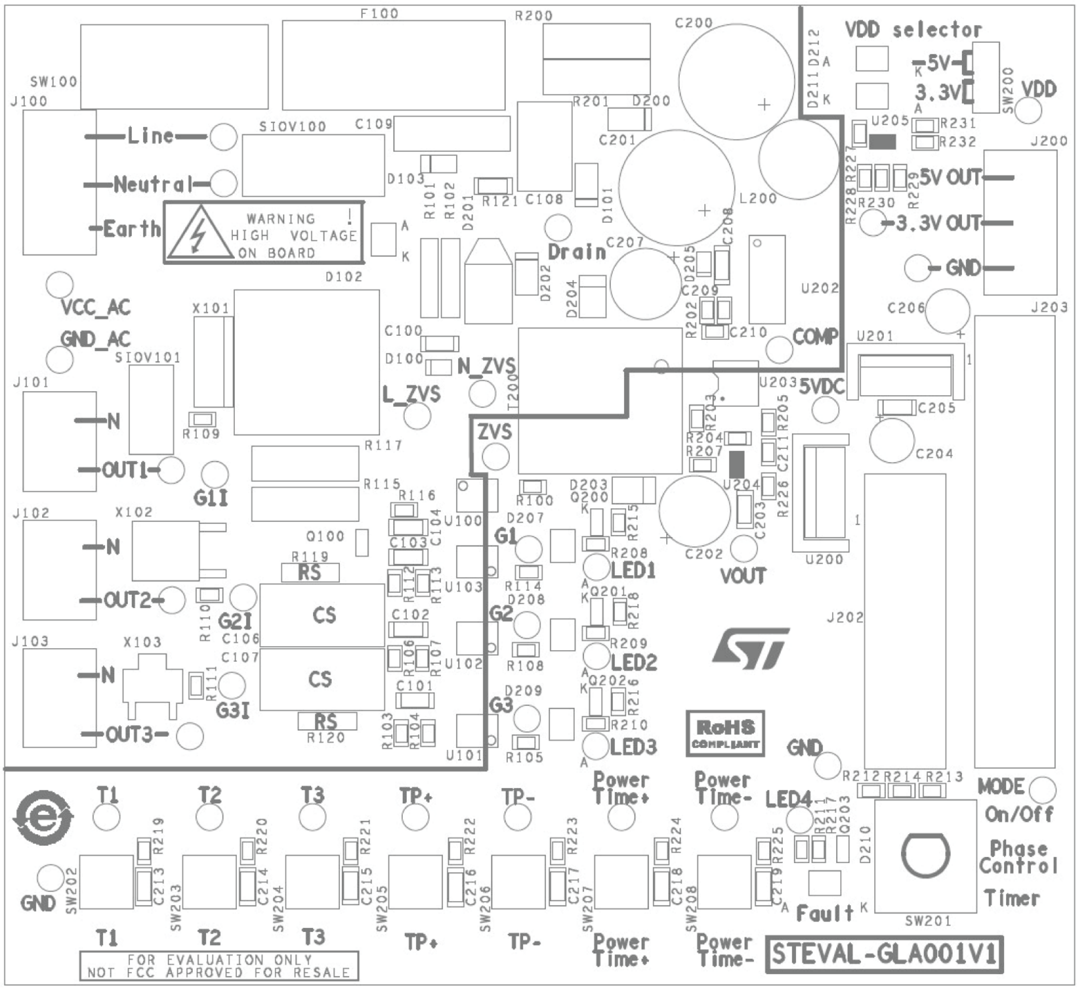


Figure 39. **34-Pin ST board connector**



6 STEVAL-GLA001V1 silkscreen TOP

Figure 40. STEVAL-GLA001V1 silkscreen TOP



7 Bill of materials

Table 7. **Bill of materials**

Item	Q.ty	Ref	Part/Value	Description	Manufacturer	Order code
1	11	C100,C101,C102,C103, C213,C214,C215,C216,C217,C218,C219	10nF, 50V, ceramic, +/-10%	Capacitor	AVX	12065C103KAT2A
2	1	C104	1nF, 50V, ceramic, +/-10%	Capacitor	AVX	12065C102KAT2A
3	2	C106,C107	Not connected	Capacitor		
4	1	C108	68nF, 275Vac, X2, +/-10%	Capacitor	Wurth Elektronik	890324022017CS
5	1	C109	10nF, 275Vac, X2, +/-20%	Capacitor	Epcos	B32921C3103M189
6	1	C200	22uF, 450V, Aluminium, +/-20%	Capacitor	Nichicon	UVY2W220MHD
7	1	C201	10uF, 450V, Aluminium, +/-20%	Capacitor	Nichicon	UVR2W100MHD1TO
8	1	C202	220uF, 10V, Aluminium, +/-20%, ESR < 15mohms	Capacitor	Nichicon	RL81C221MDN1KX
9	2	C203,C205	100nF, 10V, Ceramic C0G, +/-5%, low ESR	Capacitor	Kemet	C1206C104J3GACTU
10	2	C204,C206	3.3uF, 10V, Aluminium, +/-20%	Capacitor	Nichicon	UPW1H3R3MDD
11	1	C207	100uF, 30V, Aluminium, +/-20%, ESR < 30mohms	Capacitor	Nichicon	RL81V101MDN1KX
12	1	C208	1uF, 30V, Ceramic X7R, +/-10%, low ESR	Capacitor	TDK	C3216X7R1H105K160AB
13	1	C209	3.3nF, 16V, Ceramic, +/-10%	Capacitor	TDK	C2012X7R2A332K085AA
14	1	C210	Not connected	Capacitor		
15	1	C211	150n, 16V, Ceramic, +/-10%	Capacitor	TDK	C2012JB1H154K
16	2	D100,D205	BAT48Z, 350mA, 40V	Diode	ST	BAT48Z

Item	Q.ty	Ref	Part/Value	Description	Manufacturer	Order code
17	2	D101,D200	1N4007, 1A, 1000V	Diode	On Semi	1N4007
18	2	D102,D210	red LED	LED	Vishay	VLMT3100-GS08
19	1	D103	BZX79C2V4, 2.4V, 0.5W	Diode	Fairchild	BZX79C2V4
20	1	D201	1.5KE220A	Transil	ST	1.5KE220A
21	1	D202	STTH1R06, 1A, 600V	Diode	ST	STTH1R06
22	1	D203	STPS2H100, 2A, 100V	Diode	ST	STPS2H100
23	1	D204	STPS1L60, 1A, 60V	Diode	ST	STPS1L60
24	5	D207,D208,D209,D211,D212	green LED	LED	Vishay	VLMC3100-GS08
25	1	F100	FUSE 10A, 250V	Fuse	Multicomp	MC000828
26	2	J100,J200	3 points connector	Connector	Weidmuller	PM 5.08/3/90 3.5 SW -1760520000
27	3	J101, J102, J103	2 points connector	Connector	Weidmuller	PM 5.08/2/90 3.5 SW -1760510000
28	1	J202	2x10 points connector	Connector	Amphenol	T821120A1S100CEU
29	1	J203	2x17 points connector	Connector	Molex	70246-3404
30	1	L200	1mH	Inductor	Wurth Elektronik	744741102
31	1	Q100	SMBTA42, 0.5A, 300V	Transistor	Infineon	SMBTA42
32	4	Q200,Q201,Q202,Q203	2N7002, 100mA, 60V	Transistor	On Semi	2N7002
33	2	R100,R116	4.7k, 1/8W, +/-5%	Resistor	TE Connectivity	CRG0805F4K7
34	2	R101,R102	620k, 1/4W, +/-5%	Resistor	Vishay	MRS25000C6203FCT00
35	2	R103,R104	560, 1/2W, +/-5%	Resistor	Vishay	CRCW0805560RFKEAHP
36	7	R105,R108, R112,R113,R212,R214, R228	1k, 1/8W, +/-5%	Resistor	TE Connectivity	CRG0805F1K0
37	2	R106,R107	374, 1/2W, +/-5%	Resistor	Panasonic	ERJP06F3740V
38	2	R109, R202	Not connected	Resistor		
39	2	R110,R111	220, 1/8W, +/-5%	Resistor	Vishay	CRCW0805220RFKEA
40	1	R114	2k, 1/8W, +/-5%	Resistor	Multicomp	MC01W080512K

Item	Q.ty	Ref	Part/Value	Description	Manufacturer	Order code
41	2	R115,R117	150, 2W, +/-5%	Resistor	TE Connectivity	CFR200J150R
42	2	R119,R120	Not connected	Resistor		
43	1	R121	3.3k, 1/2W, +/-5%	Resistor	Vishay	CRCW12063K30FKEAHP
44	1	R200	10, 2W, +/-5%	Resistor	TE Connectivity	CFR200J10R
45	1	R201	12, 2W, +/-5%	Resistor	TE Connectivity	ROX2SJ12R
46	1	R203	3.9k, 1/8W, +/-5%	Resistor	Vishay	CRCW08053K90FKEA
47	1	R204	15k, 1/8W, +/-5%	Resistor	TE Connectivity	CRG0805F15K
48	2	R205,R230	100k, 1/8W, +/-5%	Resistor	TE Connectivity	CRG0805F100K
49	1	R207	100k, 1/8W, +/-0.05%	Resistor	Panasonic	ERA6ARW104V
50	6	R208,R209,R210,R211, R231,R232	1.5k, 1/8W, +/-5%	Resistor	Vishay	CRCW08051K50FKEA
51	1	R213	620, 1/8W, +/-5%	Resistor	Multicomp	MC01W08051620R
52	12	R215,R216,R217,R218,R219,R220,R221, R222,R223,R224,R225, R227	10k, 1/8W, +/-5%	Resistor	Bourns	CR0805-FX-1002GLF
53	1	R226	26.1k, 1/8W, +/-0.1%	Resistor	Panasonic	ERA6AEB2612V
54	1	R229	48.7k, 1/8W, +/-5%	Resistor	Vishay	CRCW080548K7FKEA
55	1	SIOV100	S14K300	MOV	Epcos	B72214S0301K101
56	1	SIOV101	Not connected	MOV		
57	1	SW100	Switch, 10A	Switch	Arcolectric	H8800VACL13
58	1	SW200	3 points header	Header	TE Connectivity	826936-3
59	1	SW201	Switch 3 positions	Switch	Multicomp	1MD6T1B5M1QE
60	7	SW202,SW203,SW204,SW205,SW206, SW207,SW208	micro switch	Switch	TE Connectivity	FSM4JSMA

Item	Q.ty	Ref	Part/Value	Description	Manufacturer	Order code
61	37	TP100...102, 104… 117, 200… 203, 205, 207, 211, 212, 214… 217, 219… 226	Test point	Test point	Vero Technologies	20-2136
62	1	T200	Transformer	Transformer	Myrra	74015
63	4	U100,U101,U102,U103	TLP187	Optocoupler	Toshiba	TLP187
64	1	U200	LF50ABV	Voltage regulator	ST	LF50ABV
65	1	U201	LF33ABV	Voltage regulator	ST	LF33ABV
66	1	U202	viper16HD	AC-DC converter	ST	Viper16HD
67	1	U203	PC817X	optocoupler	Sharp LiteOn	PC817X LTV817
68	1	U204	TS431AILT, 1.24V	Voltage reference	ST	TS431AILT
69	1	U205	TSV631ILT	OPAmp	ST	TSV631ILT
70	1	X101	T1635T-8FP	Triac	ST	T1635T-8FP
71	1	X102	ACST310-8B	ACST	ST	ACST310-8B
72	1	X103	ACS108-8TN	ACS	ST	ACS108-8TN

8 Test points

Table 8. Test points

Voltage reference	Name	Description
Referenced to high voltage (connected to mains voltage)	Line	Mains voltage line
	Neutral	Mains voltage neutral (after input switch and fuse)
	Drain	Viper drain
	L_ZVS	Line on optocoupler for ZVS function
	N_ZVS	Neutral on optocoupler for ZVS function
	COMP	Viper comp pin
	VCC_AC	Positive non regulated auxiliary power supply point
	GND_AC	Reference non regulated auxiliary power supply point
	G1I	T1 gate signal
	G2I	T2 gate signal
	G3I	T3 gate signal
	OUT1	T1 A2 voltage
	OUT2	T2 OUT voltage
	OUT3	T3 OUT voltage
Referenced to insulated voltage (insulated from mains voltage)	VDD	Power supply (5V or 3.3V)
	3.3V OUT	3.3V power supply
	GND	GND
	5VDC	5V power supply
	VOUT	Flyback output voltage
	ZVS	ZVS signal
	G1	T1 gate signal
	G2	T2 gate signal
	G3	T3 gate signal
	LED1	LED1 signal
	LED2	LED2 signal
	LED3	LED3 signal
	MODE	MODE signal
	LED4	LED4 signal
	T1	T1 push button signal
	T2	T2 push button signal
	T3	T3 push button signal
	TP+	TP+ push button signal
	TP-	TP- push button signal
	Power Time +	Power Time + push button signal
	Power Time -	Power Time - push button signal

9 AC switch gate control dimensioning

Gate current I_G is required to switch an AC switch ON. This I_G current should be higher than the triggering gate current I_{GT} given in the AC switch datasheet. This parameter is temperature dependent, so recalculation is required if a parameter like ambient temperature changes.

The STEVAL-GLA001V1 evaluation board embeds three AC switches and all gate control circuits have been calculated to ensure turn-on for ambient temperature from 0 to 60 °C. It also takes into account fluctuation on VCC_AC voltage (non-regulated auxiliary voltage referenced to mains voltage) from approximatively 13 V to 21 V. In case of schematic use in another design, you must recalculate the gate control circuit, especially the R_G resistor (R103 or R106 or R115+R117 pair). Refer to the formulas below to adjust R_G resistor values.

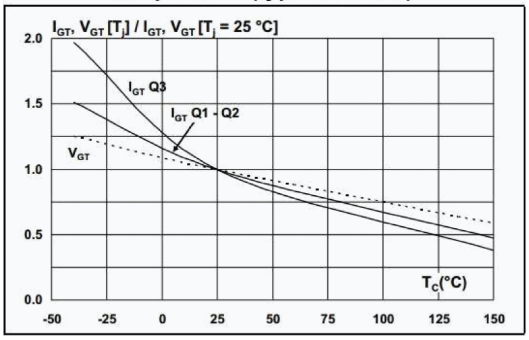
X101 Triac

X101 is a T1635T-8FP Triac. The figure below gives the I_{GT} parameter value and its variation versus the temperature

Figure 41. T1635T-8FP datasheet extract

Symbol	Test conditions	Quadrant		Value	Unit
I_{GT} (1)	V_D = 12 V, R_L = 30 Ω	I - II - III	Min.	1.75	mA
			Max.	35	
V_{GT}	V_D = 12 V, R_L = 30 Ω	I - II - III	Max.	1.3	V

Figure 8. Relative variation of gate trigger current and gate voltage versus junction temperature (typical values)



At 0 °C ambient temperature I_{GT} * 1.26 = 44 mA is needed to ensure Triac activation. Considering this current and VCC_AC minimum voltage, the gate resistors calculation is:

$$\left(R115 + R117\right) = \frac{V(R115 + R117)}{I_G(\min)} = \frac{V_{CC\_AC}(\min) + V_{GT}(\max) - V_{CEsat}}{I_G(\min)} = \frac{13 + 1.3 - 0.5}{44 \times 10^{-3}} = 313\ \Omega$$

The nearest normalized value is 150 Ω.

You can calculate maximum power in the resistors considering VCC_AC maximum voltage:

$$I_G(\max) = \frac{V(R115 + R117)}{R115 + R117} = \frac{V_{CC\_AC}(\min) + V_{GT}(\max) - V_{CEsat}}{R115 + R117} = \frac{21 + 1.3 - 0.5}{300} = 73\ mA$$

$$P_{R115} = R115 \times I^2_{G(\max)} = 0.8\ W$$

Therefore, R115 and R117 are 150 Ω/2 W resistors.

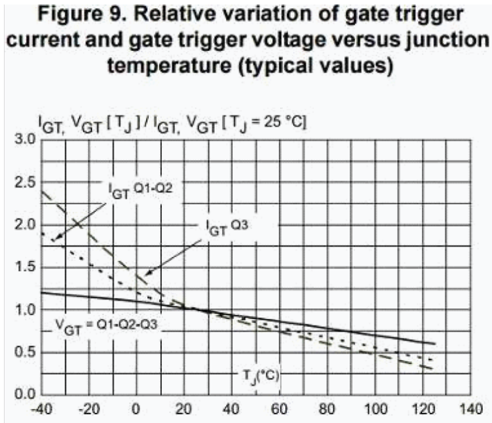
Note: Use the above formulas to recalculate resistor values in case of schematic use in another design with a different ambient temperature.

X102 AC switch

X102 is an ACST310-8B AC switch. The figure below gives the I_{GT} parameter value and its variation against temperature.

Figure 42. **ACST310-8B datasheet extract**

Symbol	Test conditions	Quadrant	T_j	Value		Unit
I_{GT}[1]	V_{OUT} = 12 V, R_L = 33 Ω	I - II - III	25 °C	Max.	10	mA
V_{GT}				Max.	1.1	V



At 0 °C ambient temperature, I_{GT} * 1.4 = 14 mA is required to ensure Triac activation. Gate-cathode resistor (R_{GK} = R110) current should be considered in the calculation as it is significant. In this case, the required I_G is:

$$I_G(\min) = \frac{V_{GT}}{R110} + 14\,mA = \frac{1.1}{220} + 14\,mA = 19\,mA$$

Considering this current value and the VCC_AC minimum voltage, the gate resistor calculation is:

$$\left(R106 + R107\right) = \frac{V(R106 + R107)}{I_G(\min)} = \frac{V_{CC\_AC}(\min) + V_{GT}(\max) - V_{CEsat}}{I_G(\min)} = \frac{13 + 1.1 - 0.3}{19 \times 10^{-3}} = 726\,\Omega$$

The nearest normalized value is 374 Ω.

You can calculate maximum power in the resistors considering VCC_AC maximum voltage:

$$I_G(\max) = \frac{V(R106 + R107)}{R106 + R107} = \frac{V_{CC\_AC}(\min) + V_{GT}(\max) - V_{CEsat}}{R106 + R107} = \frac{21 + 1.1 - 0.3}{748} = 29\,mA$$

$$P_{R106} = R106 \times I_{G(\max)}^2 = 0.31\,W$$

Therefore, R106 and R107 are 374 Ω/0.5 W resistors.

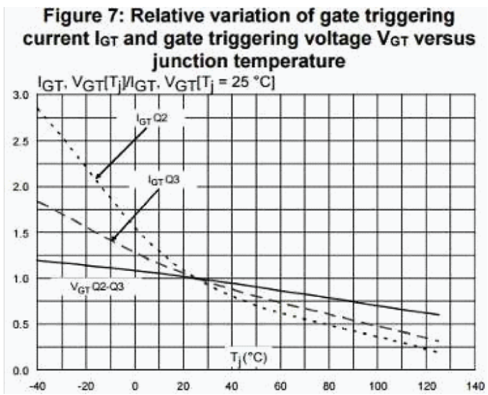
Note: *Use the above formulas to recalculate resistor values in case of schematic use in another design with a different ambient temperature.*

X103 AC switch

X103 is an ACS108-8TN AC switch. The figure below gives the I_{GT} parameter value and its variation against temperature.

Figure 43. **ACS108-8TN datasheet extract**

Symbol	Test Conditions	Quadrant		Value	Unit
I_{GT}[1]	V_{OUT} = 12 V, R_L = 33 Ω	II - III	Max.	5	mA
V_{GT}		II - III	Max.	1	V



At 0 °C ambient temperature, I_{GT} * 1.6 = 8 mA is required to ensure Triac activation. Gate-cathode resistor (R_{GK} = R111) current should be considered in the calculation as it is significant. In this case, the required I_G is:

$$I_G(\text{min}) = \frac{V_{GT}}{R111} + 14\ mA = \frac{1}{220} + 8\ mA = 12.5\ mA$$

Considering this current value and the VCC_AC minimum voltage, the gate resistor calculation is:

$$\left(R103 + R104\right) = \frac{V(R103 + R104)}{I_G(\text{min})} = \frac{V_{CC\_AC}(\text{min}) + V_{GT}(\text{max}) - V_{CEsat}}{I_G(\text{min})} = \frac{13 + 1 - 0.3}{12.5 \times 10^{-3}} = 1096\ \Omega$$

The nearest normalized values are 560 Ω.

You can calculate maximum power in the resistors considering the VCC_AC maximum voltage:

$$I_G(\text{max}) = \frac{V(R103 + R104)}{R103 + R104} = \frac{V_{CC\_AC}(\text{min}) + V_{GT}(\text{max}) - V_{CEsat}}{R103 + R104} = \frac{21 + 1 - 0.3}{1120} = 19\ mA$$

$$P_{R103} = R103 \times I^2_{G(\text{max})} = 0.21\ W$$

Therefore, R103 and R104 are 560 Ω/0.5 W resistors.

Note: Use the above formulas to recalculate resistor values in case of schematic use in another design with a different ambient temperature.

10 STEVAL-GLA001V1 power losses

STEVAL-GLA001V1 board generates limited standby power losses due to the components directly connected to the mains voltage and to the secondary side power supply, including:

- ZVS circuit
- LED circuit (high voltage presence)
- MODE switch circuit
- Power supply regulation circuit (secondary)
- LED circuit (VDD voltage)

Standby power losses measurement has been performed using a power meter under the following conditions:

- Vmains = 240 Vrms / 60 Hz
- Tamb = 22 °C
- VDD = 5 V (worst case)
- MODE switch in On/off position (worst case)

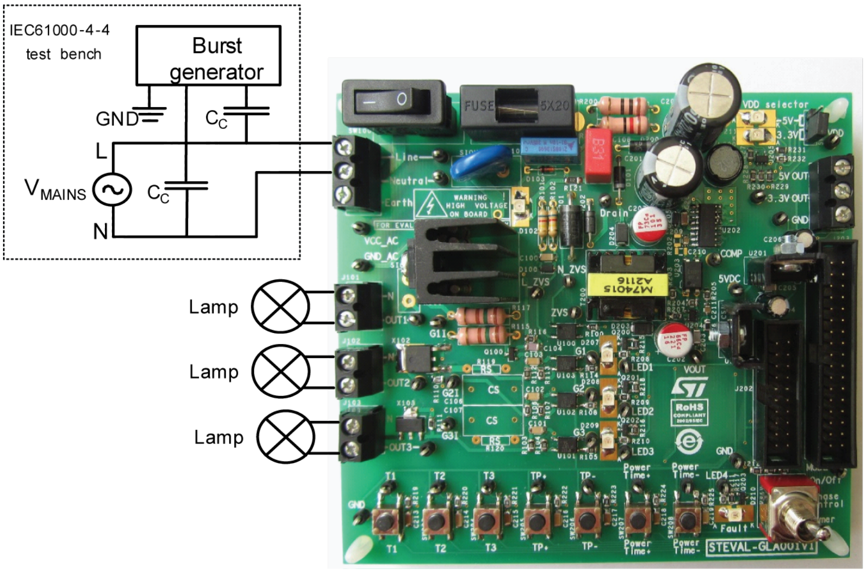
Table 9. Typical STEVAL-GLA001V1 standby losses

Vmains	I(input)	P(input)
240 V / 60 Hz	10 mA	288 mW

11 IEC61000-4-4 performance

STEVAL-GLA001V1 AC switches have been tested according to IEC61000-4-4 test. This test allows assessment of the AC switch robustness against electrical fast transients. The test schematics are shown below.

Figure 44. **IEC61000-4-4 test with STEVAL-GLA001V1**



Measurements were performed under the following conditions:

- Vmains = 230 Vrms / 50 Hz
- Tamb = 22 °C
- Nucleo board connected and supplied by STEVAL-GLA001V1
- 5 kHz - burst duration = 15 ms and repetitive burst period = 300 ms
- 100 kHz - burst duration = 0.75 ms and repetitive burst period = 300 ms
- Test duration: 1 minute

1. **Criteria A:** The aim of this test is to withstand 2 kV transient under normal operation (no abnormal behavior allowed during and after the test). For this criteria, the test is done twice: first with X101 in phase control mode (to check the normal AC switch operation) and with X102 and X103 OFF (to check that there is no spurious turn-on); the second time with X103 in phase control mode and with X101 and X102 OFF.
2. **Criteria B:** The aim of this test is to withstand 4 kV transient with normal operation at the end of the test (operation temporary disturbed allowed if followed by a self-recovery). For this criteria, the test is done twice: first with X101 in phase control mode (to check the normal AC switch operation) and with X102 and X103 OFF (to check if there is spurious turn-on); the second time with X103 in phase control mode and with X101 and X102 OFF.
3. **Tests results:** Tests results are given in following table.

Table 10. **IEC61000-4-4 test results**

Frequency	5 kHz				100 kHz			
Coupling	L+	L-	N+	N-	L+	L-	N+	N-
2 kV Criteria A	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
4 kV Criteria B	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

12 AC switch performance improvements

You can improve AC switch performance in several ways, such as adding a snubber, a R_{GK} or a varistor. The following table summarizes the configurations.

Table 11. Tips for AC switch performance improvement

AC switch	IEC61000-4-5 or overvoltage	IEC61000-4-4 or dV/dt	Commutation
X101	Add a MOV (strongly recommended)	Add a R_{GK}	No need
X102	No need	Modify R_{GK} or add a snubber	Add a snubber
X103	No need	Modify R_{GK} or add a snubber	Add a snubber

The following tips can help improve the behavior for each AC switch reference.

1. X101 Triac

   X101 is a snuberless Triac; it doesn’t need a snubber to improve commutation performance. You should add a varistor to protect the Triac against overvoltage: varistor reference depends on the applied voltage level. You can also add a R_{GK} to improve dV/dt robustness and therefore IEC61000-4-4, if higher than 2 kV criteria A (or 4 kV criteria B) levels are required.
2. X102 AC switch

   X102 is an overvoltage protected AC switch; it doesn’t need a varistor to protect it against overvoltage. You can add a snubber to improve commutation performance. You can also modify the R_{GK} value (R110) or add a snubber to improve dV/dt robustness and therefore IEC61000-4-4 if higher levels are required.
3. X103 AC switch

   X103 is an overvoltage protected AC switch; it doesn’t need a varistor to protect it against overvoltage. You can add a snubber to improve commutation performance. You can also modify the R_{GK} value (R111) or add a snubber to improve dV/dt robustness and therefore IEC61000-4-4 if higher levels are required.

Revision history

Table 12. **Document revision history**

Date	Version	Changes
04-Dec-2017	1	Initial release.
23-Mar-2018	2	Minor text changes.

Contents

List of tables

List of figures