UM1631

User manual

Getting started with the STEVAL-IHT005V2 evaluation board with full 3.3 V ACS/ triac control

Introduction

The STEVAL-IHT005V2 evaluation board is designed for the home appliances, focusing on the demonstration of a robust solution with a 3.3 V supplied 32-bit MCU.

Target applications are mid-end and high-end washing machines, dishwashers, and dryers with different kinds of ACS/triacs.

The evaluation board is based on the 48-pin, 32-bit STM32F100C4T6B MCU running at 24 MHz (RC user-trimmable internal RC clock), featuring 16 kBytes of Flash memory, 12-bit A/D converter, five timers, communication interfaces, and 4 kBytes of SRAM.

The power supply circuitry is based on VIPER16LN, an offline converter with an 800 V avalanche rugged power section, operating at 60 kHz. The power supply provides negative 6 V in buck-boost topology.

The STEVAL-IHT005V2 can control two high-power loads up to 2830 W thanks to T1635H 16 A, 600 V high temperature triac, and up to 2050 W thanks to the ACST1635-8FP 16 A, 800 V high temperature overvoltage-protected ACST device.

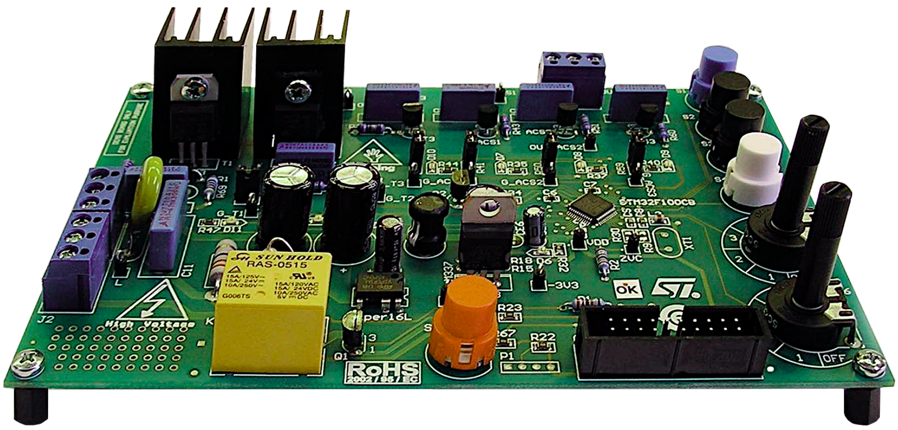
The high power load control is based on phase angle control. To limit the inrush current and possible current peaks, the evaluation board features a soft-start routine and a smooth power change function for high-power loads.

The STEVAL-IHT005V2 can also control four low-power loads up to 100 W thanks to three ACS108-8SA, 0.8 A, 800 V overvoltage-protected ACS devices, and a Z0109MA 1 A standard four-quadrant 600 V triac.

The evaluation board passed the precompliance tests for EMC directives IEC 61000-4-4 (burst up to 8 kV) and IEC 61000-4-5 (surge up to 2 kV).

The STEVAL-IHT005V2 has an overall standby power consumption below 500 mW at 264 V/50 Hz.

Figure 1. **STEVAL-IHT005V2 evaluation board**



1 Getting started

1.1 Safety instructions

Warning:

The high-voltage levels used for the STEVAL-IHT005V2 evaluation board operation could present a serious electrical shock hazard. This evaluation board has to be used in a suitable laboratory by qualified personnel only, familiar with the installation, use, and maintenance of power electrical systems.

1.1.1 Intended use

The STEVAL-IHT005V2 evaluation board is designed for demonstration purposes only, and has not to be used for domestic or industrial installation.

For technical data and information about power supply and working conditions, refer to the documentation included in the board package and strictly observe them.

1.1.2 Installation

Warning:

Follow and strictly observe the installation instructions of this user manual for the STEVAL-IHT005V2 evaluation board.

Protect the components against excessive strain. In particular, do not bend the components and do not alter isolating distances during transportation, handling, or use.

Danger:

Do not touch electronic components and contacts. The STEVAL-IHT005V2 evaluation board contains electrostatic sensitive components that could be damaged if not properly used.

Do not damage electrical components to prevent potential risks and health injury.

1.1.3 Electrical connections

Follow the applicable national accident prevention rules when working on the mains power supply. Complete the electrical installation in accordance with the appropriate requirements (that is, cross-sectional areas of conductors, fusing, PE connections). In particular, disconnect the programming device from the board JTAG connector when the board is plugged into the mains.

1.1.4 Board operation

A system architecture, which supplies power to the evaluation board, must be equipped with additional control and protective devices in accordance with the applicable safety requirements (for example, compliance with technical equipment and accident prevention rules).

Warning:

Do not touch the board after disconnection from the mains power supply, as several parts and power terminals, which contain possibly charged capacitors, need to discharge completely.

1.2 Board aim

The STEVAL-IHT005V2 evaluation board demonstrates a complete solution for home appliance applications based on ST components. In particular, it demonstrates a robust 3.3 V solution, which successfully passed the 4 kV level in class A IEC-61000-4-4 (burst) test.

This board also allows you to check AC switches control feasibility with a 3.3 V supply.

You can measure the gate currents and compare them to AN2986 measurements.

The board embeds the following devices:

- STM32F100C4T6B value line 32-bit MCU;

- T1635H-6T 16 A 600 V 35 mA high temperature snubberless triac in TO-220 package;
- ACST1635-8FP 16 A 800 V high temperature overvoltage-protected AC switch in TO-220 FPAB package;
- ACS108-8SA 0.8 A 800 V 10 mA overvoltage-protected ACS device in TO-92 package;
- Z0109MA 1 A standard 10 mA 4Q triac in TO-92 package;
- VIPER16LN offline converter with 800 V avalanche rugged power section operating at 60 kHz.

You can control the ACS108-8SA and Z0109MA in on and off modes through buttons. These devices control small loads like valves, pumps, and door locks.

Potentiometers allow you to control the T1635H-6T and ACST1635-8FP in phase control mode. These devices control high-power loads like drum motors or heating resistors.

1.3 Features

- Complete solution for -3.3 V control
- Input voltage range: 90-265 V_{AC} 50/60 Hz
- Negative 6 V/3.3 V V_{DC} auxiliary power supply based on the VIPer16L in buck-boost topology
- Total power consumption in standby mode is lower than 0.5 W for 264 V/50 Hz
- 48-pin, 32-bit value line family STM32F100C4T6B MCU as main controller
- Zero voltage switching (ZVS) interrupt to synchronize MCU events with voltage mains
- One T1635H-6T and one ACST1635-8FP for phase control of high-power loads
- Five discrete power level states with soft change for phase-angle controlled devices
- One Z0109MA and three ACS108-8SA for full wave control of low-power loads
- One relay for demonstration of the board noise robustness
- Red LED to show that the board is supplied from mains
- Green LED for each ACS/ACST/triac to show that the device is turned on
- JTAG programming connector
- External wire loop for gate-current measurement
- I²C bus hardware/software ready
- Eighteen test pins
- IEC 61000-4-4 precompliance test passed (burst up to 8 kV)
- IEC 61000-4-5 precompliance test passed (surge up to 2 kV)
- RoHS compliant

1.4 Target applications

Target applications are mid-end and high-end washing machines, dishwashers, dryers, and coffee machines.

This board also targets any home-appliance application where the STM32 MCU controls any type of triac/ACST/ACS.

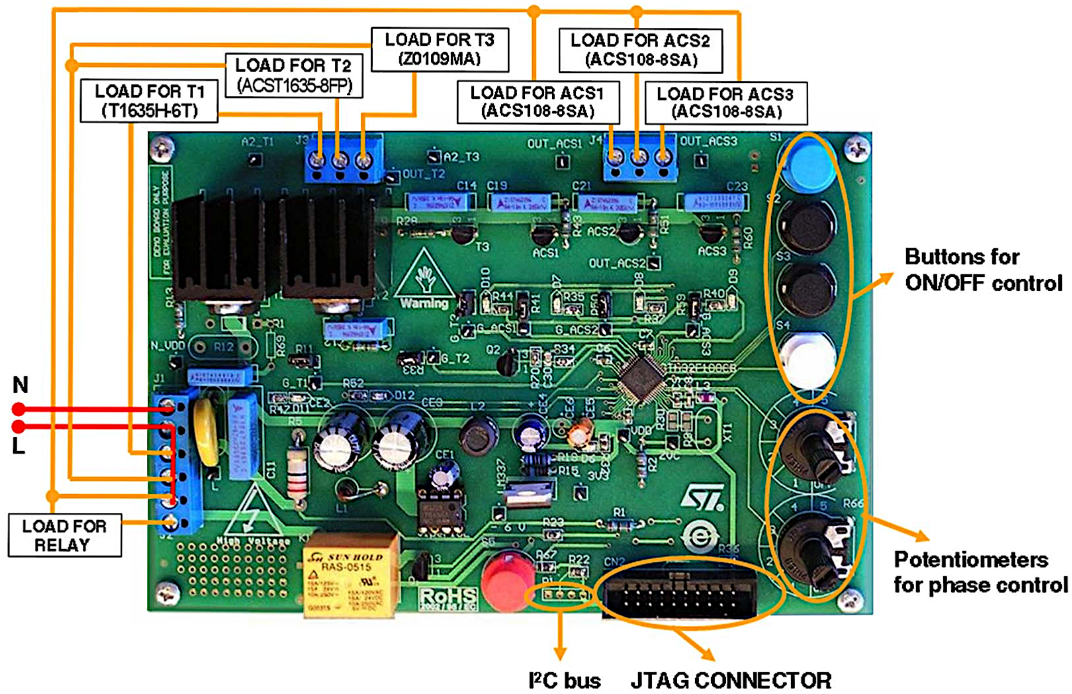
1.5 Operating conditions

The board operates in nominal line voltage 110 V/230 V in both 50/60 Hz power nets.

- Line voltage: 90-264 V 50/60 Hz
- Operating ambient temperature: 0°C to 60°C
- Nominal load power (for 230 V voltage)
- ACST1635-8FP: 2050 W
- T1635H-6T: 2830 W
- Z0109MA: 96 W
- ACS108-8SA: 105 W

1.6 Board connections

Figure 2. **STEVAL-ITH005V2 connections**



Important: *Connect loads and voltage probes before applying line voltage.*

2 STEVAL-IHT005V2 operation

Connect the line voltage as shown in Figure 2. The evaluation board can work with or without the load. Even if no load is connected, all signals are present and can be displayed on the oscilloscope.

Red LED (D6) signals that the board is properly supplied from the mains. It also signals that high voltage is present on the evaluation board.

Turn both potentiometers to the off position before powering the evaluation board. The board is ready to operate after passing all initialization routines, like mains frequency recognition, that take approximately 2 seconds.

R65 potentiometer controls T1 (T1635H-6T) and R66 potentiometer controls T2 (ACST1635-8FP).

You can adjust the output power level by changing the position of the related potentiometer.

Power regulation is divided in five steps where position 1 means minimum power and position 5 means maximum power.

D11 LED for T1 (T1635H-6T) and D12 LED for T2 (ACST1635-8FP) signal that the gate control signal is applied. If the load (example motor) is running and the LED lights up, it indicates that the MCU is properly controlling the triac.

Blue, black, and white buttons control the three ACS108-8SA devices and Z0109MA in on/off mode with zero-voltage synchronization. The blue button (S1) controls ACS1, the black button (S2) controls ACS2, the other black button (S3) controls ACS3 and the white button (S4) controls T3. The different colors help to identify easily the controlled device.

ACS2 and ACS3 are controlled with 2 ms gate pulses. This is sufficient for loads with an RMS current approximately in the range of 100 mA - 500 mA. Smaller loads should be controlled through ACS1, which has continuous gate control.

T3 is controlled with 2 ms pulses and is used for comparison with ACS2 and ACS3 behavior.

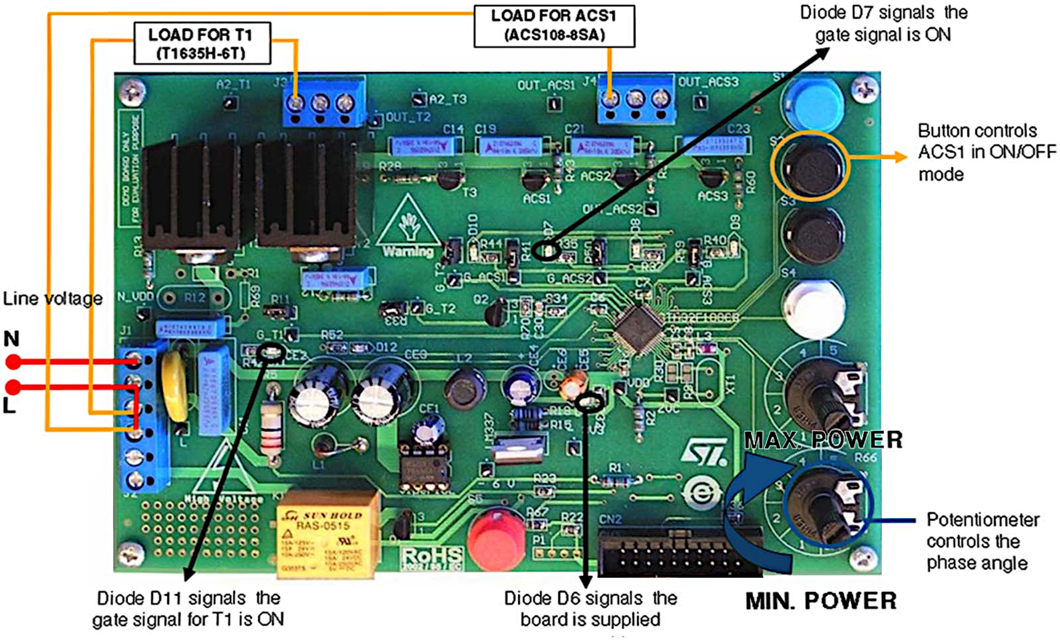
D10 LED for T3 (Z0109MA), D7 LED for ACS1 (ACS108-8SA), D8 LED for ACS2 (ACS108-8SA), and D9 LED for ACS3 (ACS108-8SA) indicate that the gate control signal is applied.

The red button (S5) controls relay (R1) in continuous DC mode. The DC control starts at zero voltage for control coil.

Note: The coil control at zero voltage does not lead to an accurate zero voltage switching (ZVS) of the power contacts.

The button control is used in a two-step control. When you push the button for the first time, it turns the related device on. A second push of the button turns the related device off. All devices controlled by buttons are in the off position after reset.

Figure 3. STEVAL-ITH005V2 operation overview



3 MCU programming

Once the evaluation board has the mains cable and load cable correctly connected, you can power it on. The STEVAL-IHT005V2 evaluation board enters wait-for-signal mode immediately after powering it on.

To modify the software, a JTAG connector for MCU programming is necessary.

Warning:

The programming device has to be galvanically isolated from mains when programmed directly on mains.

4 Load and gate control fitting

The MCU generates gate current pulse. Through the software, you can set the pulse length. Its value must be set according to the minimum load current. The load current has to reach the AC switch latching current value to keep the device on after the gate pulse is removed. Latching current (IL) is specified in the AC switch datasheet.

Important:
Check this point for low power loads when RMS current is low and it takes a long time to reach the latching current level.

When gate current is removed before the load current reaches the latching current, the device might turn off.

The maximum value and length of the gate current that the board can provide depends on the power supply rating. The power supply used in the evaluation board is able to provide 120 mA continuously in the operating voltage full range.

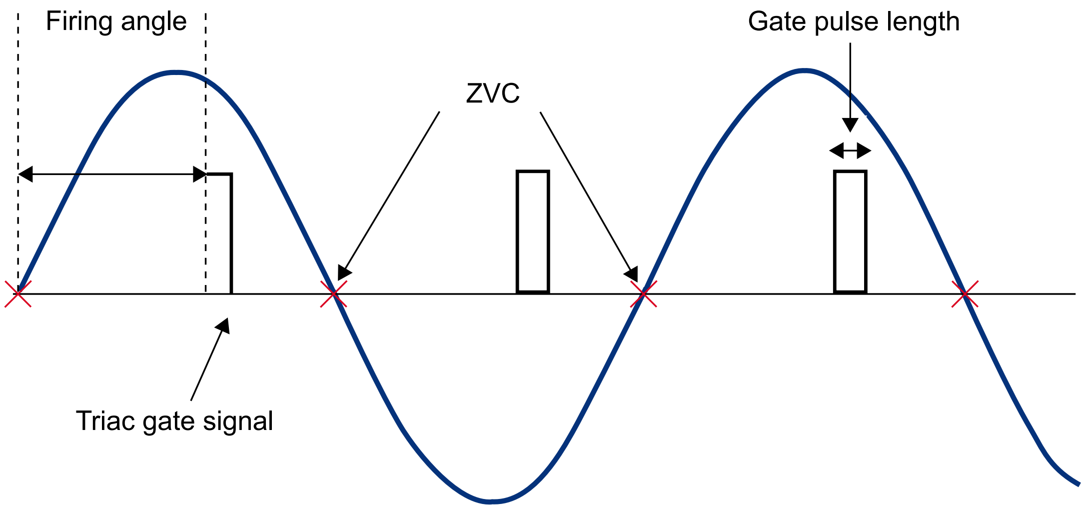
5 Functional description

Two different types of ACS/triac control are implemented: phase angle control and full wave control. The gate control signal is synchronized with zero-voltage-crossing signal (ZVC). The MCU operation is also synchronized with ZVC signal. The latter is sent directly to the MCU input pin that is set as external interrupt.

5.1 Phase angle control

Control of T1 (T1635H-6T) and T2 (ACST1635-8FP) is based on phase angle control.

Figure 4. Phase angle control description



Phase angle control is based on changing the firing angle (delay). The firing angle determines the power that is delivered to the load. The shorter the firing angle (delay), the higher the power.

Firing angle and gate control pulse are defined through software.

Table 1. Default settings of firing angle delay

Level 1	Level 2	Level 3	Level 4	Level 5
8.5 ms	6.9 ms	5.2 ms	3.6 ms	2.0 ms

5.2 Full wave control

Control of T3 (Z0109MA), ACS1, ACS2, and ACS3 (all ACS108-8SA) is based on full wave pulse control.

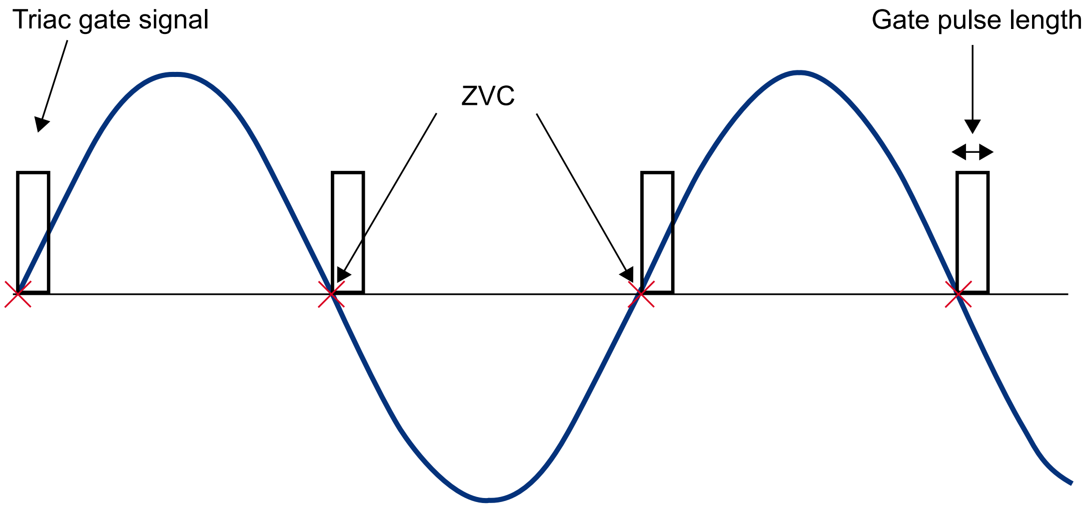


Figure 5. Full wave control description

Full wave pulse control is based on sending gate control pulse immediately after ZVC signal. Gate control pulse length is defined by the software.

Table 2. Default gate current pulse duration for 50 Hz mains

Device	Variable name for 50 Hz mains	Initial gate pulse duration (ms/timer steps)(1)
ACS1	ACS_1_SWITCHTIME_50HZ	10/100
ACS2	ACS_2_SWITCHTIME_50HZ	2/20
ACS3	ACS_3_SWITCHTIME_50HZ	2/20
Z0109MA	Z0109_SWITCHTIME_50HZ	2/20
ACST1635-8FP	ACST16_SWITCHTIME_50HZ	1/10
T1635H-6T	T1635H_SWITCHTIME_50HZ	1/10

1. *The timer step is 100 µs.*

Table 3. Default gate current pulse duration for 60 Hz mains

Device	Variable name for 60 Hz mains	Initial gate pulse duration (ms/timer steps)(1)
ACS1	ACS_1_SWITCHTIME_60HZ	8.3/83
ACS2	ACS_2_SWITCHTIME_60HZ	1.6/16
ACS3	ACS_3_SWITCHTIME_60HZ	1.6/16
Z0109MA	Z0109_SWITCHTIME_60HZ	1.6/16
ACST1635-8FP	ACST16_SWITCHTIME_60HZ	0.8/8
T1635H-6T	T1635H_SWITCHTIME_60HZ	0.8/8

1. *The timer step is 100 µs.*

6 Power supply consumption

6.1 Maximum output current and standby consumption

Nonisolated SMPS based on the VIPER16LN in buck-boost topology is designed to provide output voltage of -6 V. The maximum output current is 120 mA.

The LM337 linear regulator provides the -3.3 V voltage necessary to supply the MCU.

Standby consumption has been measured in the supply voltage full range. The standby power consumption fulfills the requirement of maximum total power consumption below 500 mW.

The board total power consumption in standby mode, at supply voltage of 264 Vrms/50 Hz, is 499 mW (10 mA output current at -6 V output voltage).

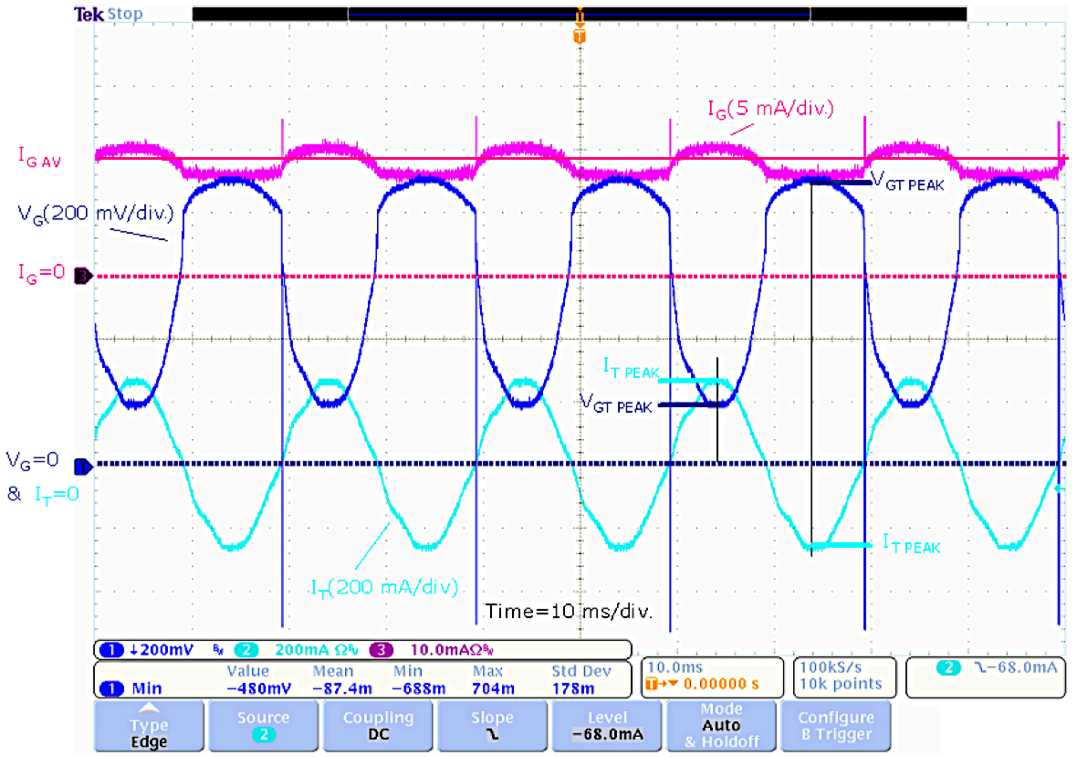
The power supply uses mains voltage for self-supply from the high-voltage current generator.

Standby power consumption can be reduced by using the configuration with VIPER16LN supply made from the low voltage side. Refer to the AN2872 and VIPER16 datasheet for further information on the power supply design.

6.2 Gate voltage impact on gate current

The figure below shows how the gate voltage V_{GT} varies with load current. In this example, load current is in quadrants 2 and 3 (0.2 A RMS) for Z0109MA with T_j = 85°C and I_{G0} = 7.5 mA. This variation is significant mainly for devices that are controlled in DC mode and with a low power supply level of 3.3 V.

Figure 6. Example of V_{GT} variation



ACS devices have lower V_{GT} variation with load current than triacs. Thus, they are more suitable for 3.3 V applications as the gate current variation is lower.

Refer to AN2986 for further details and for gate resistor calculation.

6.3 Pulsed gate control and average gate current consumption

The table below lists the initial gate current pulse widths for each AC switch. It also lists the maximum pulse width that can be programmed to keep the overall consumption below the maximum capability of the VIPER16LN supply.

Table 4. Application current consumption

Device	PCB label	Gate resistor[Ω]	I_{GT} (T_j = 25°C) [mA]	I_{GT} (T_j = 0°C) [mA]	Gate current pulse duration [ms]	Maximum average current [mA]	Max. gate current pulse duration (DC mode) [ms]
T1635H-6T	T1	30	35	50	1	5	N.A.[1]
ACST1635-8FP	T2	30	35	50	1	5	N.A.[1]
Z0109MA	T3	112	10	15	2	3	10
ACS108-8SA	ACS1	112	10	15	10	15	10
ACS108-8SA	ACS2	112	10	15	2	3	10
ACS108-8SA	ACS3	112	10	15	2	3	10

1. *The device is controlled in phase angle control. Long pulse is not desired.*

The current consumption of the MCU and of six signal LEDs, when turned on, has been estimated at 25 mA. The total current consumption of the board, when all triacs/AC switches are on with the maximum gate current pulse, is 95 mA.

7 Board immunity performance

7.1 Hardware and software features to increase immunity

The software features implemented to improve board immunity are:

- Filtering procedure for button and potentiometer control
- Watchdog

The hardware features implemented to improve board immunity are:

- Input varistor
- ACS-ACST technology and Transil as an option for T1635H-6T
- 47 nF input X2 capacitor
- Noise suppressor circuits (10 nF X2 capacitor and 75 Ω resistor)
- R-C-R filter on gate (RG/2, 10 nF, RG/2)

The layout rules for immunity improvement are:

- Power tracks far from signal tracks
- V_{SS} map
- Noise suppressor and R-C-R gate filter close to AC switches and triacs
- Input MCU pins with a 10 nF filter capacitor
- Any branch in the V_{DD} map has a capacitor to decrease the V_{DD} variation

7.2 Surge test results

Standard IEC 61000-4-5 tests have been performed with a surge level of 2 kV, which is required for home appliances. The mains voltage used for the tests was 230 Vrms/50 Hz.

The ACST1635-8FP is protected against overvoltage spikes up to 2 kV with implemented crowbar technology.

ACS108-8SA devices are protected against overvoltage spikes up to 2 kV with implemented crowbar technology. See the ACS108-8SA datasheet for further details.

The Z0109MA triac is protected thanks to the noise suppressor circuit and high impedance of the load (refer to AN437 for snubber design).

The P6KE400CA Transil protects the T1635H-6T. This is a different implementation of the crowbar technology. This method has the advantage of not aging differently from the varistor technology.

7.3 Burst test results

7.3.1 Test procedure

Standard IEC 61000-4-4 tests have been performed at a frequency of 100 kHz and a power supply voltage of 254 Vrms/50 Hz. The spike parameters were T_d = 0.7 ms, T_r = 300 ms. All affected couplings have been tested. Spikes were applied against the plate and related polarity (+/-) with the mains wires (L+, L-, N+, N-, LN+, LN-). The board has been tested in off state (that is, all AC switches were turned off).

Protective earth (PE) wire is not connected on the board. Consequently, the couplings with PE have not been tested.

7.3.2 Test results of the board without hardware modifications

The target voltage level of the board immunity against burst spikes was 4 KV without any influence on the board performance (class A).

Burst spikes up to 6 kV (class A) did not disturb the STM32F100C4T6B MCU. Burst spikes up to 8 kV caused the MCU to reset but it recovered without any external intervention (class B). Reset procedure did not influence the immunity of the devices with higher immunity.

The table below shows the immunity level of the ACS/triacs against the burst spikes. The voltage level of spurious triggering defines the immunity.

Table 5.

STEVAL-IHT005V2 V_{IN} 254 V_{AC} - 50 Hz	L+	L-	N+	N-	LN+	LN-
T1635H-6T (150 W light bulb load)	>8 kV	>8 kV	>8 kV	>8 kV	>8 kV	>8 kV
ACST1635-8FP (150 W light bulb load)	>8 kV	>8 kV	>8 kV	>8 kV	>8 kV	>8 kV
Z0109MA (75 W light bulb load)	4.5 kV	4.1 kV	3.7 kV	4.6 kV	4.0 kV	3.7 kV
ACS1 (75 W light bulb load)	7.4 kV	6.7 kV	>8 kV	7.1 kV	7.3 kV	7.0 kV
ACS2 (150 W light bulb load)	>8 kV	>8 kV	>8 kV	>8 kV	7.6 kV	7.1 kV
ACS3 (150 W light bulb load)	>8 kV	>8 kV	>8 kV	>8 kV	7.6 kV	7.1 kV

7.3.3 Input filter influence

A 47 nF, X2 capacitor is implemented as input filter. To achieve 4 kV immunity against the burst spikes for all AC switches, we added two other X2 capacitors (100 nF and 220 nF). Each of them influenced a different type of coupling. The STEVAL-IHT005V2 board does not include these two capacitors as only Z0109MA was below 4 kV level.

Table 6. IEC-61000-4-4 results with input filter modification

STEVAL-IHT005V2 V_{IN} 254 V_{AC} - 50 Hz	2 kV	4 kV	6 kV	8 kV
Standby + L On + level 3 (5.2 ms)	A	A	B	B
Standby + N On + level 3 (5.2 ms)	A	A	B	B
Standby + L +N On + level 3 (5.2 ms)	A	A	B	B
Standby - L On + level 3 (5.2 ms)	A	A	B	B
Standby - N On + level 3 (5.2 ms)	A	A	B	B
Standby - L +N On + level 3 (5.2 ms)	A	A	B	B

Note:
- *A. No changes in functionality. The board works properly, no reset occurring.*
- *B. Reset occurs, but the board recovers without any external intervention.*
- *C. Application does not recover without an external intervention.*

We tested two states: standby mode, when all devices are off, and “on + level 3" when all devices are turned on. The devices controlled in full wave mode (T3, ACS1, ACS2, ACS3) are on for the whole period and phase angle controlled devices (T1, T2) are on at level 3 (5.2 ms delay after zero voltage crossing signal).

7.3.4 Noise suppressor influence

The noise suppressor circuit that consists of X2 capacitor 10 nF (C2, C12, C14, C19, C21, C23) and resistor 75 Ω(R13, R19, R28, R43, R51, R60) has significant influence on burst immunity of the devices, as shown in the tests results below.

Table 7. Immunity of the high power devices without RC noise suppressor

STEVAL-IHT005V2 V_{IN} 254 V_{AC} - 50 Hz	L+	L-	N+	N-	LN+	LN-
T1635H-6T (150 W light bulb load)	1.7 kV	1.6 kV	1.9 kV	1.7 kV	2.1 kV	1.7 kV
ACST1635-8FP (150 W light bulb load)	4.6 kV	3.5 kV	4.8 kV	3.1 kV	3.3 kV	3.1 kV

7.3.5 Gate filtering circuit influence

The gate filtering circuit influences sensitive devices. When the gate filtering circuit is removed, the Z0109MA immunity decreases to 2 kV and ACS108-8SA immunity decreases to 4 kV. Gate filtering circuit is not mandatory to pass IEC-61000-4-4 tests for ACS108-8SA.

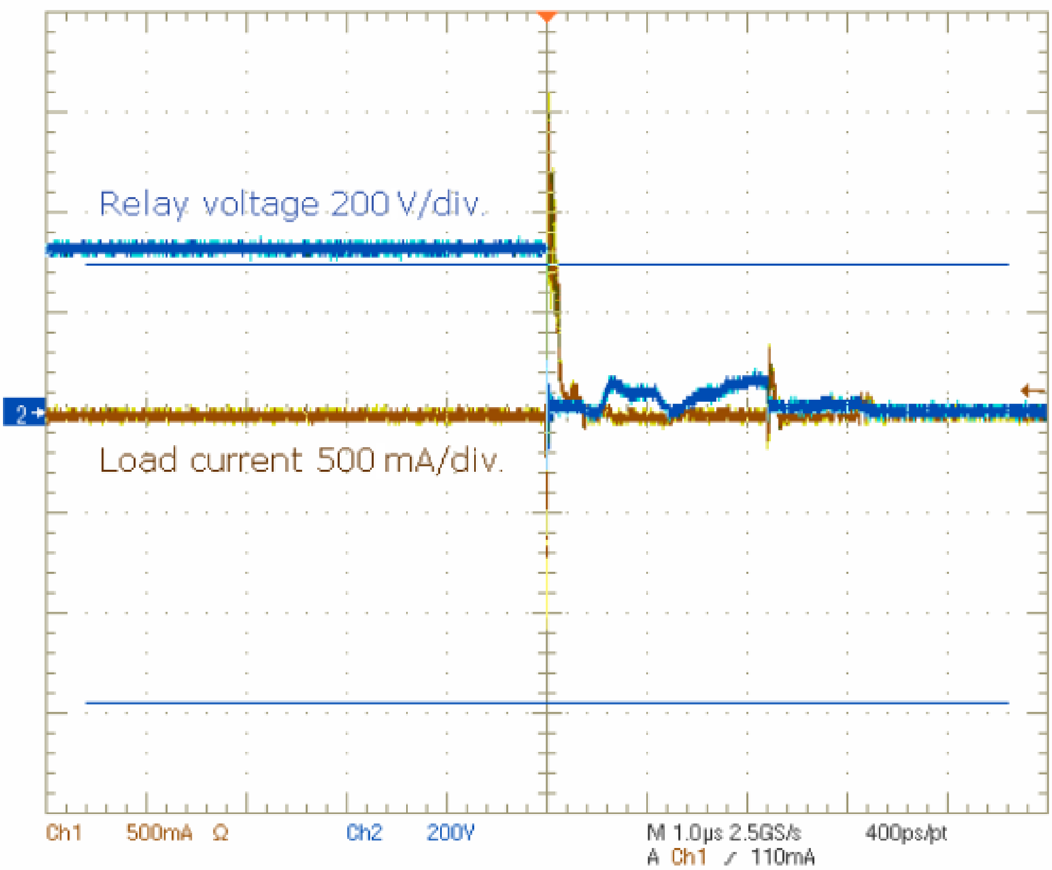
There is no influence on 35 mA I_{GT} devices when the gate filtering circuit is removed.

7.3.6 Immunity to relay switching

Relay is connected on the board. The relay cannot be controlled in zero voltage mode. Switching of the relay produces very high dV/dt. We tested the immunity of the devices against relay switching.

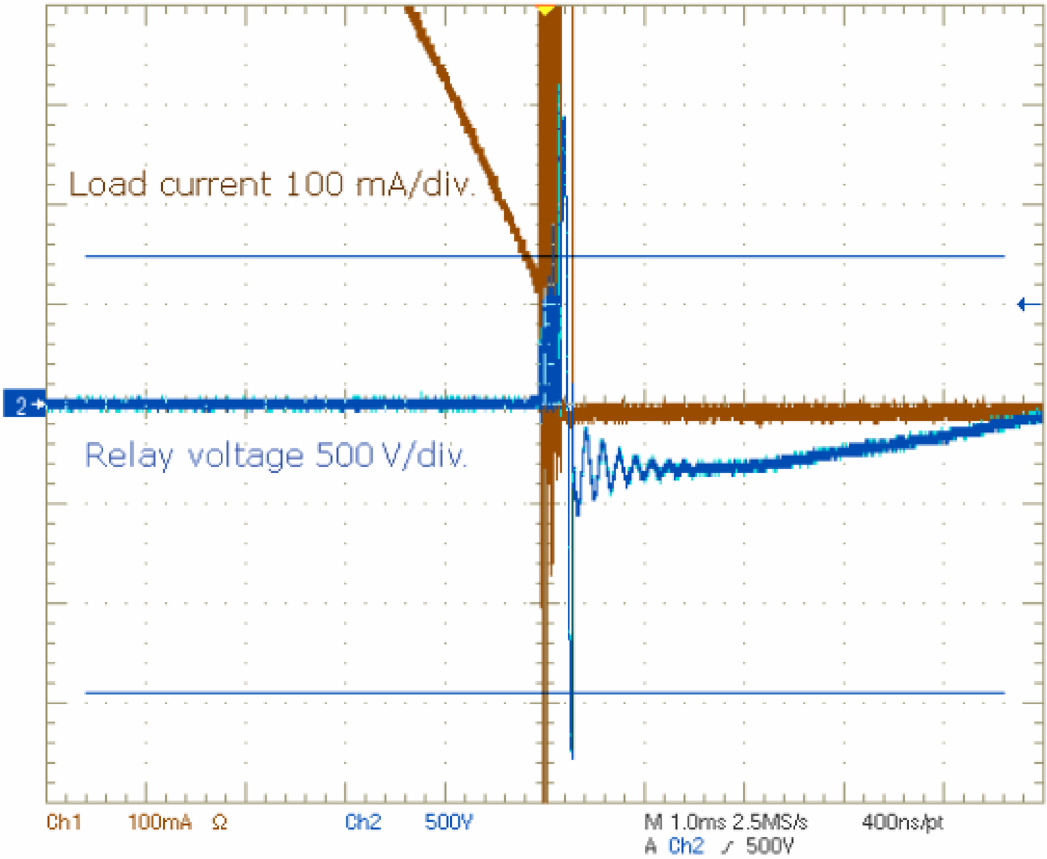
The figure below shows turn-off behavior of the relay. The dV/dt observed during turn-off is 1 kV/µs. Observed peak voltage during turn-off was ±1300 V.

Figure 7. dV/dt behavior during relay turn-off



The figure below shows turn-on behavior of the relay. The dV/dt observed during turn-on was 4 kV/µs. The load was a 1.4 H inductor with a serial resistance of 12 Ω, and RMS current of 0.52 A. The triacs and ACS/ACST switches were not disturbed by these spikes.

Figure 8. dV/dt behavior during relay turn-on



8 Board layout

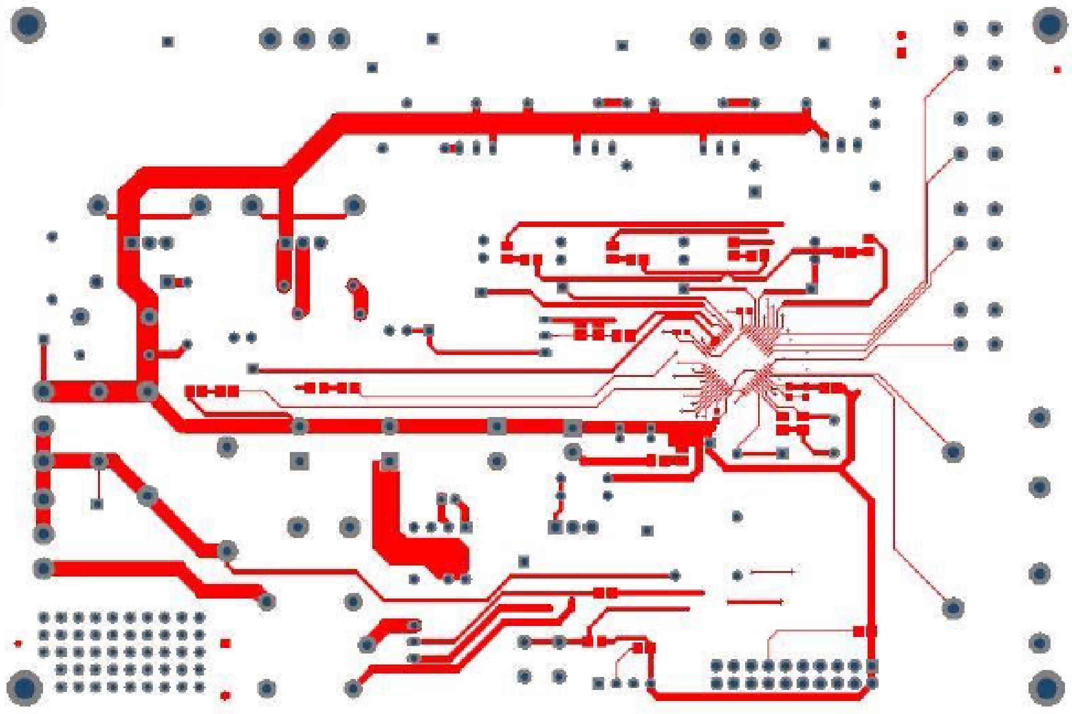


Figure 9. STEVAL-IHT005V2 top layer

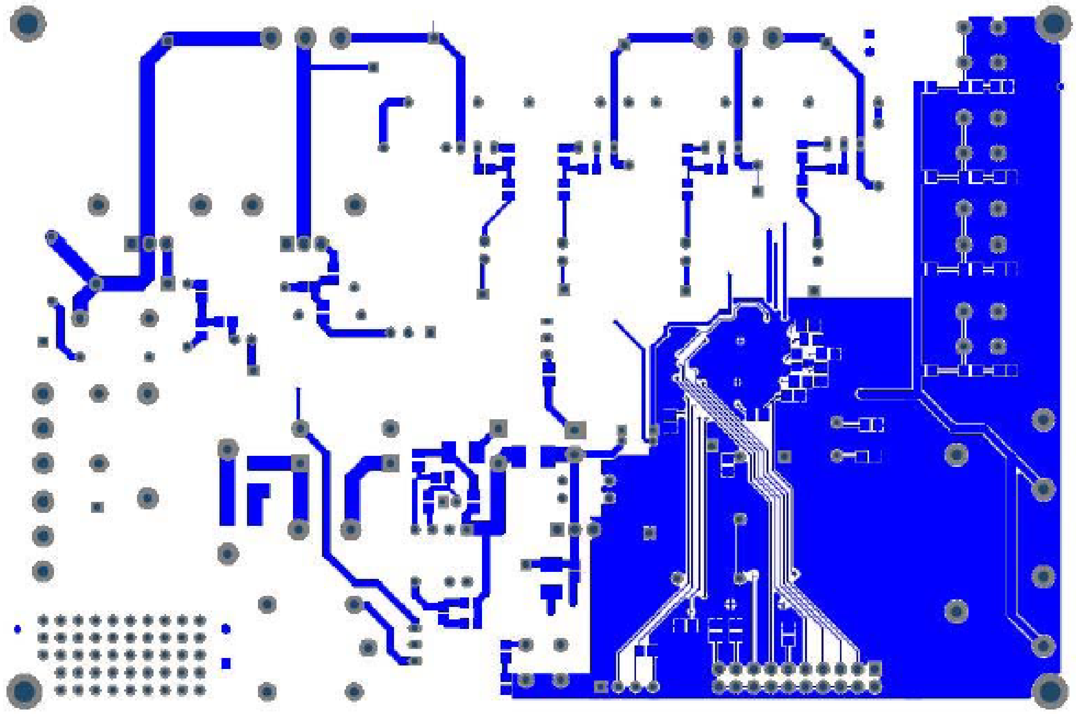


Figure 10. STEVAL-IHT005V2 bottom layer

9 Test points

Table 8. **List of test points**

Name	Description
G_T1	Control signal of T1 (T1635H-6T)
ZVC	Zero voltage crossing signal
-6 V	Reference of SMPS output voltage
N_VDD	Neutral reference and VDD
-3.3 V	Reference for MCU power supply
A2_T1	A2 terminal of T1
VDD	MCU power supply voltage
OUT_T2	Out terminal of T2 (ACST16)
G_T3	Control signal of T3 (Z0109)
A2_T3	A2 terminal of T3
G_T2	Control signal of T2 (ACST16)
G_ACS1	Control signal of ACS1
OUT_ACS1	Out terminal of ACS1
G_ACS2	Control signal of ACS2
OUT_ACS2	Out terminal of ACS2
G_ACS3	Control signal of ACS3
OUT_ACS3	Out terminal of ACS3
Line	Line voltage

10 Gate resistor calculation

The gate resistor value must be defined within the equation below to apply a gate current higher than the specified I_{GT} for the worst operating conditions.

$$R_g \leq \frac{1}{\left(1 + \frac{R_g - tol}{100}\right)} \cdot \frac{V_{DD} - Min - V_{GT} - Max - V_{OL}}{I_G(0°C)}$$

We assume that:

- V_{DD_Min} is the minimum supply voltage (typically 3 V for 3.3 V power supply taking into account dispersion of resistors at LM337)
- V_{GT_Max} = 1.0 V (maximum gate voltage that must be applied between gate and A1 or COM)
- V_{OL} = 0.4 V maximum MCU I/O port voltage when switched to low level (given by the datasheet (0.4 V for STM32F100))

Note: V_{OL} value of 0.4 V is used also for BC547B buffer transistor control.

- R_{g_tol} is the tolerance of the used resistor (typically 1% or 5%).
- I_G (0°C) is the gate current for the minimum ambient temperature (normally 0°C). Refer to Triac family datasheet curve.

The table below shows the standard resistor choices, according to the above equation and assumptions.

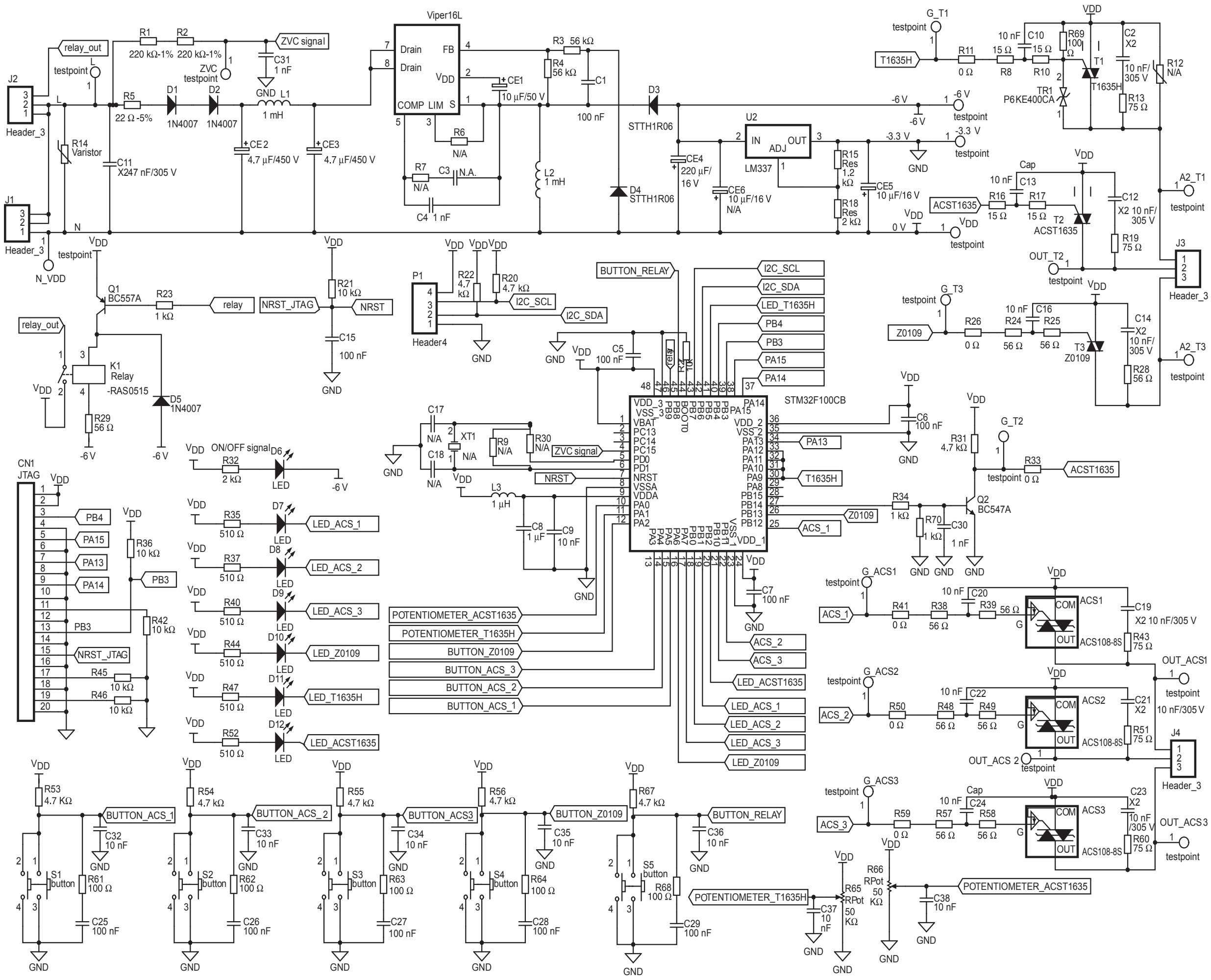
Table 9. Gate resistor definition for each device

Device	Tolerance of R_g (%)	R_g (Ω)	R_g standard (Ω)
T1635H-6T	1	31.7	2 x 15
	5	30.4	2 x 15
ACST1635-8FP	1	31.7	2 x 15
	5	30.4	2 x 15
ACS108-8SA	1	112.2	2 x 56
	5	107.8	2 x 51
Z0109MA	1	112.2	2 x 56
	5	107.8	2 x 51

The STEVAL-IHT005V2 uses tolerance resistors of 1%.

11 Schematic diagram

Figure 11. STEVAL-IHT005V2 circuit schematic



12 Bill of materials

Table 10. STEVAL-IHT005V2 bill of materials

Item	Q.ty	Reference	Part/value	Description	Manufacturer	Order code
1	1	C3	-	Capacitor	Any	Any
2	1	P1	-	4-pin header	Any	Any
3	2	C17, C18	-	Capacitors	Any	Any
4	2	R6, R7	-	Resistors	Any	Any
5	2	R9, R30	-	Resistors	Any	Any
6	1	C11	X2 47 nF/305 V	Capacitor	EPCOS	B32922C3473K000
7	6	C2, C12, C14, C19, C21, C23	X2 10 nF/305 V	Capacitors	EPCOS	B32921C3103K000
8	1	C1	100 nF	Capacitor	GME	906-096
9	1	C4	1 nF	Capacitor	GME	906-094
10	1	C8	1 µF	Capacitor	GME	972-094
11	1	C9	10 nF	Capacitor	GME	972-014
12	1	CE1	10 µF/50 V	Electrolytic capacitor	GME	123-058
13	1	CE4	220 µF/16 V	Electrolytic capacitor	GME	123-134
14	1	CE5	10 µF/16 V	Electrolytic capacitor	GME	123-048
15	1	CE6	-	Electrolytic capacitor	GME	
16	1	CN2	MLW20G	Connector	GME	800-036
17	1	D6	RED	Typical LED	GME	960-024
18	1	K1	Relay-RAS 0515	Single-pole single-throw relay	GME	634-246
19	1	L1	1 mH	Inductor	GME	611-011
20	1	L2	1 mH	Inductor	GME	611-171
21	1	L3	1 µH	Inductor	GME	965-084
22	1	Q1	BC557A	PNP bipolar transistor	GME	210-037
23	1	Q2	BC547A	NPN general purpose amplifier	GME	210-025
24	1	R12	N/A	Varistor	GME	
25	1	R14	595-275	Varistor	GME	115-034
26	1	R15	1.2 k	Resistor	GME	110-075
27	1	R18	2 k	Resistor	GME	110-080
28	1	R28	56	Resistor	GME	110-043
29	1	R31	4k7	Resistor	GME	110-089
30	1	R32	2 k	Resistor	GME	901-609
31	1	R5	22 R ±5%	Resistor	GME	114-044
32	1	R69	100	Resistor	GME	110-049
33	1	S1	P-DT6BL	Button	GME	630-051

Item	Q.ty	Reference	Part/value	Description	Manufacturer	Order code
34	1	S4	P-DT6WS	Button	GME	630-049
35	1	S5	P-DT6RT	Button	GME	630-042
36	1	XT1	HC49/U 8 MHz	Crystal oscillator	GME	131-059
37	2	C30, C31	1 nF	Capacitors	GME	906-094
38	2	CE2, CE3	4 μ7 F/450 V	Electrolytic capacitors	GME	123-039
39	2	R1, R2	220 k ±1%	Resistors	GME	110-129
40	2	R3, R4	56 k	Resistors	GME	901-586
41	2	R65, R66	50 K	Potentiometer and shaft	GME	112-230,624-088
42	2	S2, S3	P-DT6SW	Button	GME	630-048
43	3	C5, C6, C7	100 nF	Capacitors	GME	972-089
44	3	D1, D2, D5	SMA	Default diode	GME	917-016
45	3	R23, R34, R70	1 k	Resistors	GME	901-178
46	4	J1, J2, J3, J4	ARK300V-3P	Three-pole terminals	GME	821-109
47	4	R8, R10, R16, R17	15	Resistors	GME	901-573
48	5	R13, R19, R43, R51, R60	75	Resistors	GME	110-046
49	5	R61, R62, R63, R64, R68	100	Resistors	GME	901-212
50	6	C10, C13, C16, C20, C22, C24	10 nF	Capacitors	GME	906-089
51	6	C15, C25, C26, C27, C28, C29	100 nF	Capacitors	GME	906-096
52	6	D7, D8, D9, D10, D11, D12	GREEN	Typical LEDs	GME	960-023
53	6	R11, R26, R33, R41, R50, R59	0	STIP line 2x and jumpers	GME	832-021,832-013
54	6	R21, R27, R36, R42, R45, R46	10k	Resistors	GME	901-176
55	6	R35, R37, R40, R44, R47, R52	510	Resistors	GME	901-409
56	7	C32, C33, C34, C35, C36, C37, C38	10nF	Capacitors	GME	906-089
57	7	R20, R22, R53, R54, R55, R56, R67	4k7	Resistors	GME	901-188
58	9	R24, R25, R29, R38, R39, R48, R49, R57, R58	56	Resistors	GME	901-389

Item	Q.ty	Reference	Part/value	Description	Manufacturer	Order code
59	18	-3V3, -6V, A2_T1, A2_T3, G_ACS1, G_ACS2, G_ACS3, G_T1, G_T2, G_T3, L, N_VDD, OUT_ACS1, OUT_ACS2, OUT_ACS3, OUT_T2, VDD, ZVC	-	Test points	RS	262-2179
60	1	T1	T1635H-6T	16 A - 600 V - 150°C H-series triac	ST	T1635H-6T
61	1	T2	ACST1635-8FP	Overvoltage-protected AC switch	ST	ACST1635-8FP
62	1	T3	Z0109MA	1 A standard triac	ST	Z0109MA
63	1	TR1	P6KE300CA	600 W TVS in DO-15	ST	P6KE300CA
64	1	U1	VIPER16LN	Energy saving 6 W high voltage converter with direct feedback	ST	VIPER16LN
65	1	U2	LM337	Three-terminal adjustable negative voltage regulators	ST	LM337
66	1	U3	STM32F100C4T6B	Mainstream value line, Arm® Cortex®-M3 MCU with 16 Kbytes of Flash memory, 24 MHz CPU, motor control and CEC functions	ST	STM32F100C4T6B
67	2	D3, D4	STTH1R06A	600 V, 1 A Turbo 2 ultrafast diode	ST	STTH1R06A
68	3	ACS1, ACS2, ACS3	ACS108-8SA	Overvoltage-protected AC switch	ST	ACS108-8SA
69	2	-	-	Heat sink connected to T1, T2	SEMIC	TP104-30
70	1	-	Wire diameter:0.75mm,length 90 mm, 1xKONPC-SPK-2, 2xKONPC-SPK-PI	Wire loop	GME	840-002,840-004
71	4	-	10 mm, KDI6M3X10	Distance columns	GME	623-071
72	4	-	6 mm	M3 screw	Any	Any

Revision history

Table 11. Document revision history

Date	Revision	Changes
29-Oct-2021	1	Initial release.
03-Nov-2021	2	Updated Section 12 Bill of materials. Minor text edits throughout the document.

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