UM1908

User manual

STEVAL-ILD004V2: leading-edge dimmer

Introduction

The purpose of this board is to propose an innovative and low cost power topology using two sensitive SCRs and a single IGBT to dim all types of lamps, including 100 - 240 V halogen lamps, SELV halogen lamps through magnetic or electronic transformers, and the new CFL and LED dimmable lamps.

The main features of this dimmer are:

- Operation for 2-wire dimmer (optional 3-wire configuration also available)
- Flicker-free operation with multiple lamps in parallel
- Leading-edge control only (compatible with all lamps commonly found on the market)
- Operation on 110 V or 230 V line rms voltage and 50 Hz or 60 Hz line frequency
- Dimmable power range (higher power is possible with larger heatsink):
  - 3 to 600 W for 230 V rms line
  - 3 to 300 W for 110 V rms line
  - power efficiency @ 230 V > 99%
  - standby losses @ 230 V < 0.3 W
- Short-circuit protection at startup
- Enhanced interface with pushbuttons; soft-start and soft-stop; memory of last setting
- Compliance with EMC standards:
  - Compliant with EN55015 (for European market)
  - Criteria A for 2 kV IEC 61000-4-5 surge and above 2.5 kV for fast transients (in accordance with IEC 61000-4-4)

This user manual describes the principle and operating conditions of the evaluation board. The performance of the board is described regarding power losses and EMC standard test results. The description of the user interface and connections will help users to set up and evaluate this dimmer.

Figure 1. STEVAL-ILD004V2 evaluation board

Contents

1 Operating principle and target application

1.1 Dimmer for CFL, LED and halogen lamps

The target application of this board is a wall dimmer for domestic or industrial use, capable of dimming all types of lamps without flicker.

With recent ecological design directives, incandescent lamps are being phased out from European and American markets, while low consumption lamps like CFL and LED are being used more and more. But halogen lamps are still in use for high power (starting at 100 W) and for G9 and R7s bases. New dimmers must therefore be compliant with a wide range of lamp technologies.

This board is designed for two-wire dimmer applications. A three-wire dimmer (Line, Neutral and Load) can also be configured on the board. This operating mode allows the dimmer supply current not to be sunk through the lamp and can prevent unwanted LED lamp light-on.

1.2 Operating principle

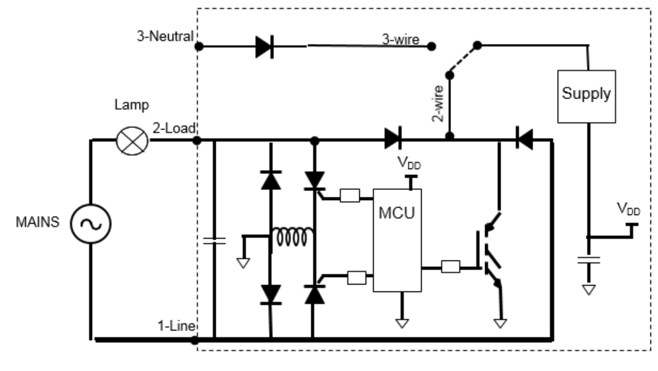
The simplified schematic of the board is shown in *Figure 2*.

Using two sensitive SCRs (T1 and T2) with very low triggering gate current (I_{GT} = 200 µA for TS820-600FP) allows a DC gate current to be applied. Then each SCR can remain on even if the lamp current is zero, as the gate is supplied up to the end of the line half-cycle. This prevents flicker.

The two SCRs are placed in back-to-back connection with a common cathode in order to obtain a single circuit to control both devices. A diode is added in reverse-parallel with each SCR. For the positive mains half-cycle, T1 and D2 conduct. For the negative mains half-cycle, T2 and D1 conduct.

An IGBT (M), placed in the diode bridge (D1, D2, D3 and D4), is used to slow down the current rising edge at dimmer turn-on and then to reduce the conducted electromagnetic noise. This IGBT avoids the necessity to use a bulky EMI filter (capacitor + inductor), which could cause slight acoustic noise.

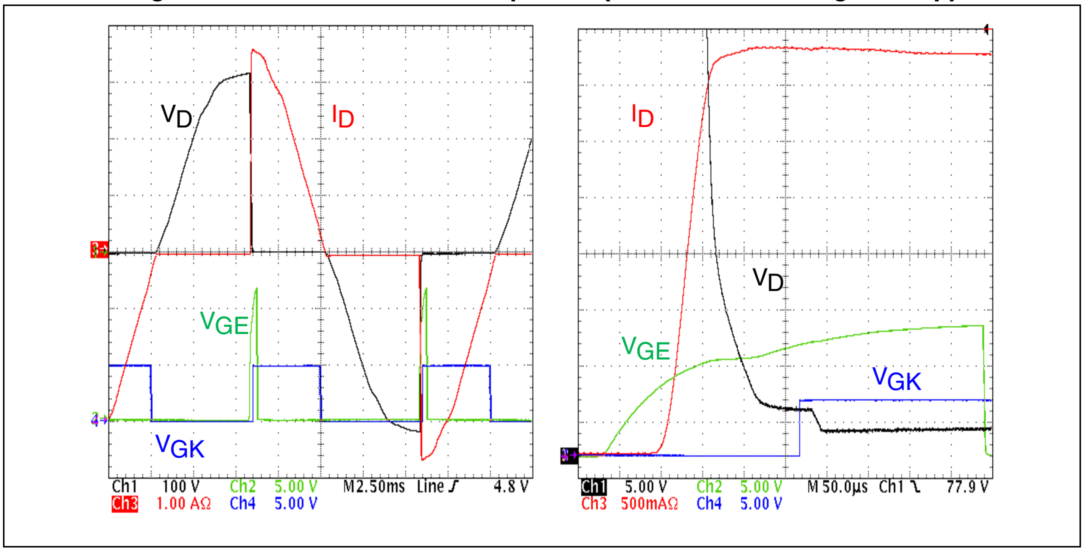
Figure 2. STEVAL-ILD004V2 simplified schematic in a two-wire configuration



The switch command sequence is shown in *Figure 3*.

The IGBT is first switched on to control the current rising edge. After 300 µs, the SCR is switched on to reduce the on-state forward voltage drop of the dimmer, and then the conduction power losses are decreased. A 2.2 µH inductor (L) is added in series with both SCRs to slow down the current variation due to the dip in voltage drop which occurs when the current switches from the IGBT to the SCR.

Figure 3. Switch command sequence (500 W, 230 V halogen lamp)



1.3 Selected components

1.3.1 Silicon controlled rectifier (SCR)

One of the main characteristics of the SCR for this application is its low gate current. The TS820-600FP features a maximum I_{GT} of 200 µA. Using the TO-220 full pack insulated package ensures just one heatsink can be used for both SCRs.

TS820-600FP main characteristics are:

- On-state rms current, $I_{T(RMS)}$ = 8 A up to a 91 °C case temperature.
- Repetitive peak off-state voltage, V_{DRM}/V_{RRM} = 600 V.
- Non repetitive surge peak on-state current for a 10 ms pulse, I_{TSM} = 70 A

1.3.2 IGBT

A 10 A 600 V IGBT, the STGF10NC60KD, is used for current commutation. This IGBT is also in full pack in order to utilize the same non-insulating heatsink for this IGBT and the two SCRs.

STGF10NC60KD main features are:

- Lower on voltage drop, $V_{CE(sat)}$ = 1.8 V typ. For I_C = 5 A and T_j = 125 °C
- Lower C_{RES} / C_{IES} ratio for better noise immunity
- Short-circuit time up to 10 µs supported.

1.3.3 Microcontroller unit (MCU)

The STM8S103F2 has been chosen because it fits well with the light dimmer application requirements. Its main features are:

- 16 MHz advanced STM8 core with Harvard architecture and 3-stage pipeline
- Program memory: 8 Kbyte Flash
- Data memory: 640 bytes true data EEPROM
- RAM: 1 Kbyte
- Up to 17 I/Os on a TSSOP 20-pin package including 12 high sink outputs
- 16-bit general purpose timer, with 3 CAPCOM channels (IC, OC or PWM)
- 8-bit basic timer with 8-bit pre-scaler

1.3.4 SMPS

A buck switch-mode power supply is implemented for the low DC voltage output (13 V), which supplies the control circuits. This buck converter is implemented thanks to a VIPer06XS device. The mains features of this devices are:

- 800 V avalanche rugged power section
- PWM operation with frequency jittering for low EMI
- Standby power < 30 mW at 265 VAC
- Switching frequency at 30 kHz

1.4 Operating conditions

The board is designed to drive all types of lamps for a wide range of applications:

- Power mains:
  - rms voltage (±10%): 100 - 120 V or 220 - 240 V
  - Frequency: 50 Hz or 60 Hz
  - Ambient temperature: 0 °C to 60 °C (closed box operation allowed; refer to *Section 2.7*)
- Supported loads:
  - Power range (total power if lamps in parallel): from 3 W to 600 W, for a 230 V rms mains voltage (300 W max for 110 V)
  - Dimmable compact fluorescent lamps
  - Dimmable LED lamps
  - Incandescent lamps
  - Halogen lamps
  - Electronic dimmable transformers
  - Magnetic transformers

2 Board performance

2.1 Two- or three-wire configuration

A mechanical switch is implemented on the STEVAL-ILD004V2 board (see SPDT switch in *Figure 4*) to allow operation in any electrical installation of the wall dimmer:

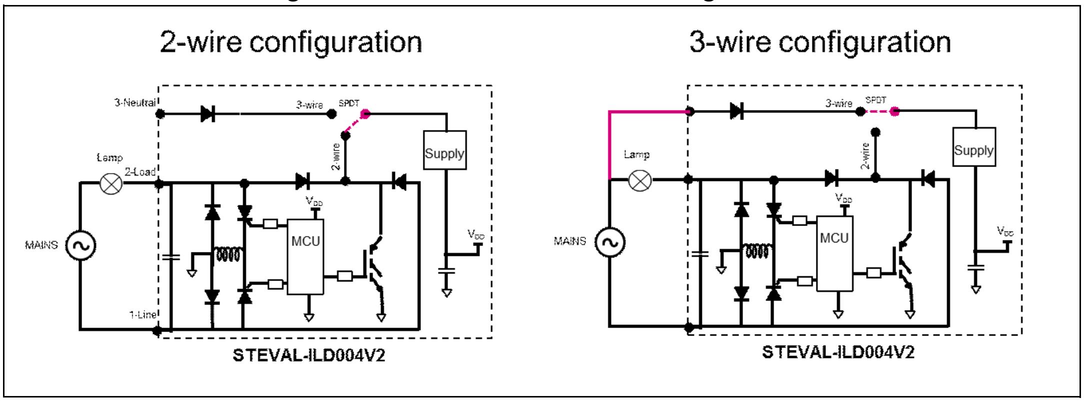
- For the two-wire configuration, the J11 header must be connected as follows:
  – J11-1: Line / Hot
  – J11-2: Load wire
  – J11-3: not connected
- For the three-wire configuration, the J11 header must be connected as follows:
  – J11-1: Line / Hot
  – J11-2: Load wire
  – J11-3: Neutral

Note: *With this wire configuration, it may also work if the SPDT switch is in the 2-wire position.*

In the three-wire topology, the current to supply the board is sunk directly from the mains thanks to the Neutral wire (if available). On the other hand, in the two-wire configuration, the current to supply the board is sunk from the mains through the lamp. The current flowing through the lamp can induce a lamp light-on at dimmer off-state, for some lamps where the embedded ballast is too sensitive to leakage current. This may occur in some low power (3-10 W) LED lamps. The possibility to switch to a three-wire configuration thus allows suppression of this unwanted lamp light-on.

The following figure shows how to connect the board in both configurations.

Figure 4. Two- and three-wire configurations



2.2 Soft-start and soft-stop

For enhanced smart control, a soft-start and a soft-stop are implemented in the software. This means that at dimmer power-on or power-off, respectively, the light increases until the last set power level (or 50% in case of 1st utilization) or decreases until lamp light off. This on/off control is activated when the on/off pushbutton is pressed for more than 100 ms.

Dimmer soft-start (or soft-stop) consists of automatically setting up every turn-on angle in the register table to the previously set value. Each step is set in 200 ms. For example, at the initial dimmer plug-in, 7 steps are required to reach mid-power. Therefore, the soft-start takes 1.4 seconds.

The programmed dimmer phase angle list is provided in *Appendix D* for 50 and 60 Hz line frequencies.

2.3 CFL and LED operation

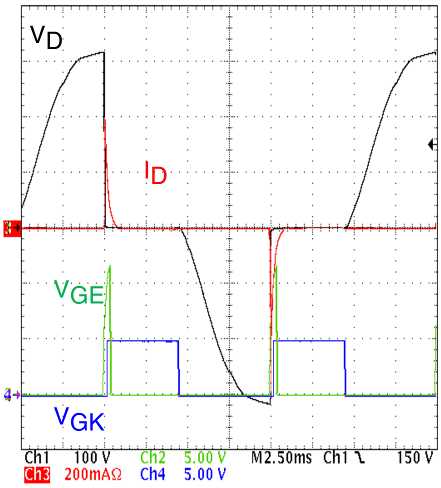
For low consumption lamps, the main issue of dimmers today is the required minimum current to keep the power switch on and to avoid lamp flickering.

Thanks to the DC gate control of the TS820, the lamp current can reach zero and the SCR remains latched, as previously explained. An example is shown *Figure 5* with an 8 W dimmable LED lamp, where the lamp current clearly goes to zero without causing any issue.

The use of a SCR for the current conduction, as opposed to a MOS-gate device, allows good operation with inductive loads and also in cases where several lamps are used in parallel.

The board can dim lamps between 36° to 144° (which is equivalent to 2 ms to 8 ms for a 50 Hz line frequency; see *Appendix D*) of the mains cycle. This induces a brightness variation from 5% to 90% of the nominal power of the lamp.

Figure 5. 8 W LED lamp dimming



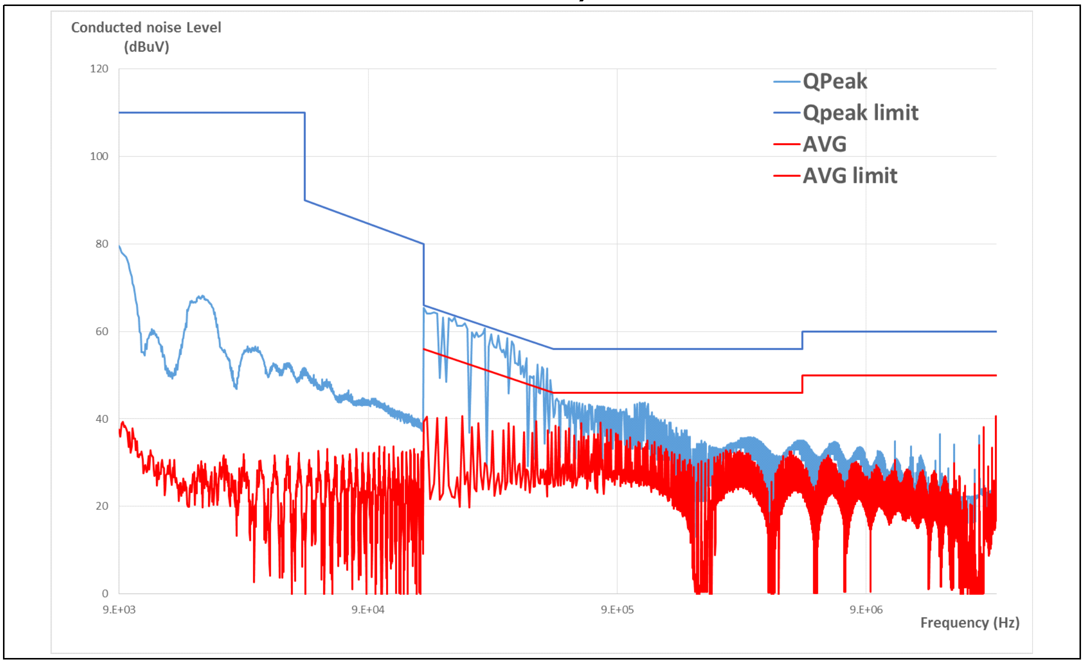
2.4 Conducted noise

EMC directives must be fulfilled for appliances sold in the European market. This dimmer, in particular, must fulfill the EN55015 standard. This standard defines the maximum levels of conducted noise due to mains current switching.

To limit this noise, the IGBT gate circuit (refer to R3 and C16 in board schematic in *Appendix A*) is designed to reduce the rising edge of the mains current.

Figure 6 illustrates the EMI noise measured according to EN55015, for the maximum switched current, i.e. for the maximum load power (a 600 W / 230 V halogen lamp) dimmed at a 5.5 ms turn-on angle (50 Hz line frequency). This illustration also shows the conducted noise for the 3-wire configuration. Note that the EMI noise level induced in the 2-wire configuration is quite similar.

Figure 6. EN55015 standard validation (600 W – 230 V halogen lamp dimmed at 5.5 ms)



2.5 Short-circuit protection

To avoid the need to add a fuse (and avoid possible issues related to its replacement) the board is self-protected against short-circuit events, which can occur if the dimmer is improperly connected.

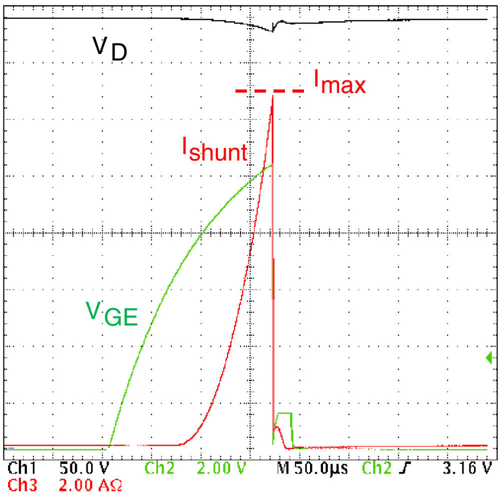
Protection is achieved with a shunt resistor (R22) used to detect overcurrent. Hardware protection using transistors Q11 and Q12 is implemented to turn off the IGBT quickly. The short-circuit information is also sent to the MCU through the PA1 I/O port.

In case of short-circuit detection, the MCU does not turn the SCRs on. An IGBT turn-on trial is performed at the next half-cycle. If the current detected by R22 is still above the defined limit (here 12.5 A, as it is the current required to reach 0.6 V through the 0.047 ohm R22 resistor), and if this occurs for four consecutive trials, the board is then definitively turned off. A red LED (D5) informs the user that a short-circuit has been detected. The only way to restart the board is to disconnect it from the power mains and plug it back in after few minutes.

Figure 7 shows the overcurrent protection in the case of triggering at peak line voltage on a short-circuited load, with a 264 V mains rms voltage (i.e. 240 V + 10%). It should be noted that, thanks to the soft-start procedure, the initial turn-on normally occurs only for a 170° turn-on delay. This means that the voltage across the dimmer should be below 50 V instead of 380 V as in the test shown in *Figure 7*. IGBT thermal stress is then greatly reduced in normal short-circuit operation.

Note that a load short-circuit usually occurs in cases of improper connection. This means that the overcurrent protection will work at first turn-on, i.e for a 170° turn-on delay. In case of lamp flash-over (which can occur at the end of life of incandescent lamps) the short-circuit occurs during dimmer conduction. The SCRs are then on and will sustain the flash-over current. Indeed this current is equivalent to a mains short-circuit (so typically around 250 A peak) but lasts typically only 1 ms. The current stress is thus equivalent to 31 A².s which is well below the specified I^2t of the TS820 (45 A^2.s).

Figure 7. Short-circuit overcurrent protection behavior

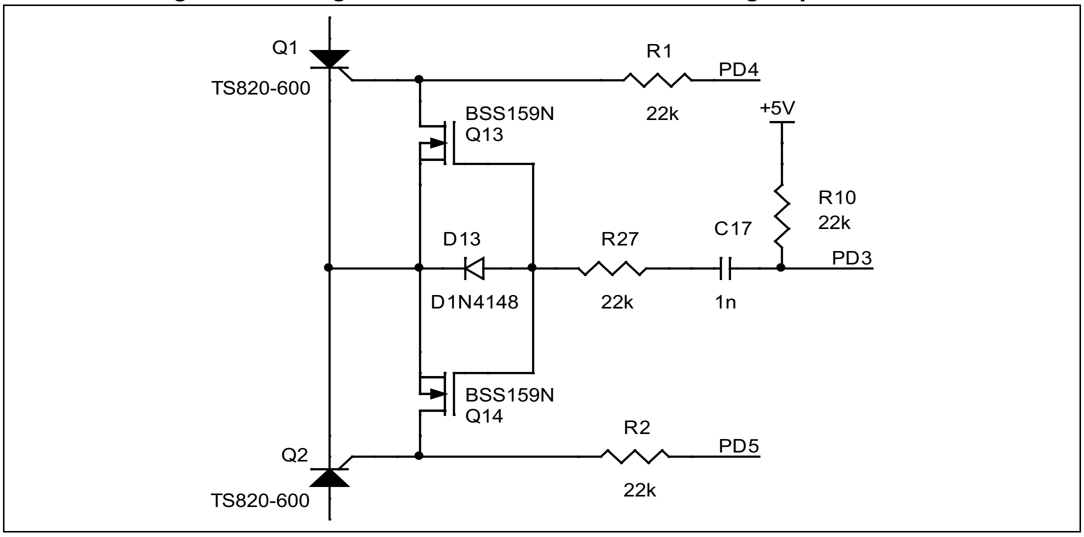


2.6 Immunity

At board plug-in, a fast voltage transient can be applied to the semiconductor switch and can exceed the SCR dV/dt capability. This is not a major issue for an SCR, which will then turn on safely and will not be damaged as long as the load current is below the SCR maximum current capability.

To avoid SCR turn-on, sensitive SCR dV/dt support can be greatly improved when its gate is short-circuited to its cathode. For this purpose, a normally-on N-MOS is connected between each SCR gate and cathode terminals (refer to Q13 and Q14 in *Figure 8*). These MOS devices are turned off thanks to C17 which charges both N-MOS gates to a negative voltage when the PD3 I/O pin is pulled down to zero.

Figure 8. SCR gate circuit for dV/dt withstanding improvement



This gate circuit also helps the board withstand fast transient voltages as described in the IEC 61000-4-4 standard. The X2 capacitor and a specific reset software routine (which allows previous configuration restoration - on or off status, set power level) allow high levels to be supported. *Table 1* gives the board's minimum supported levels according to IEC 61000-4-4 test conditions, for the different coupling modes.

Table 1. IEC61000-4-4 board minimum supported levels

Test		L-GND		N-GND	
		+	-	+	-
2-wire	5 kHz	> 6.6 kV	> 6.6 kV	> 6.6 kV	> 6.6 kV
	100 kHz	> 6.6 kV	> 6.6 kV	> 6.6 kV	> 6.6 kV
3-wire	5 kHz	> 6.6 kV	> 6.6 kV	> 6.6 kV	> 6.6 kV
	100 kHz	> 6.6 kV	> 6.6 kV	> 6.6 kV	> 6.6 kV

IEC 61000-4-4 test conditions are:

- Load is a 50 W, 230 V halogen lamp
- The minimum withstood burst level (given in *Table 1* is the maximum burst voltage, applied for 1 minute, without any lamps on)
- Mains voltage is 230 V rms / 50 Hz
- 5 kHz or 100 kHz burst frequency
- Board at 10 cm from the reference plane

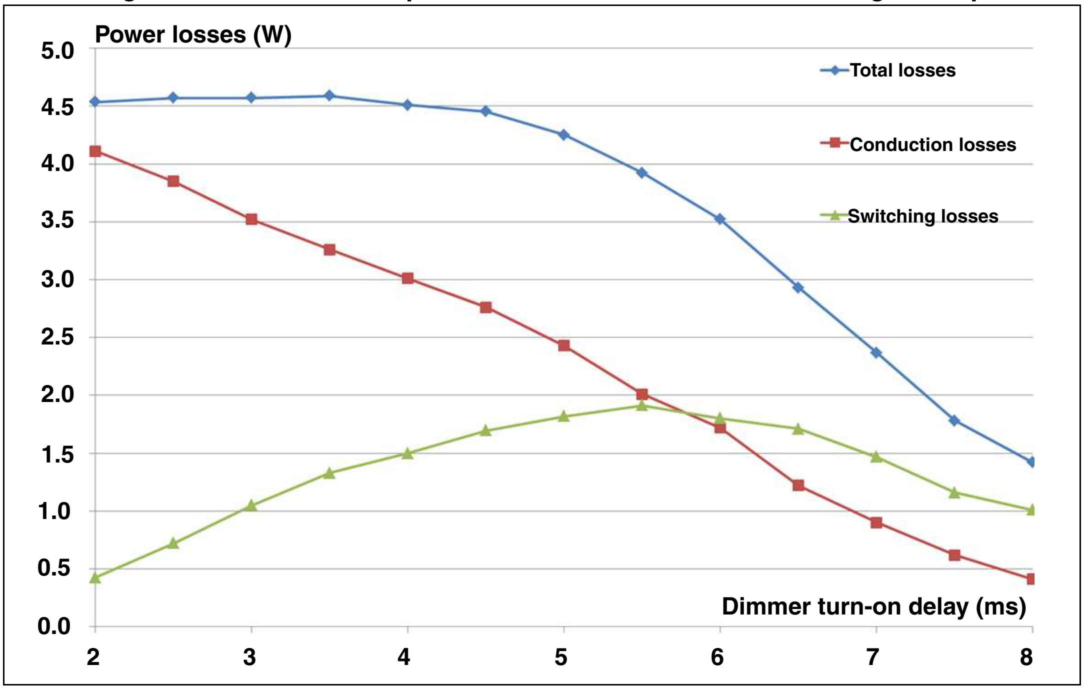
The dimmer is able to reach class A criteria up to 6.6 kV (test equipment maximum level) which is above the 2 kV required by the standard for home appliances.

2.7 Power losses

Total power losses are split into IGBT turn-on switching losses and SCR conduction losses.

Figure 9 shows the different power losses measured with a 600 W, 230 V halogen lamp, which is the worst case, and with the IGBT gate circuit which allows EN55015 to be fulfilled as shown in *Figure 6*.

Figure 9. SCR and IGBT power losses for a 600 W, 230 V halogen lamp



Maximum power losses are reached for the maximum conduction time and are lower than 4.5 W. We have performed tests in a closed box environment with limited heat transfer capability. Then, as the heatsink is placed vertically (as it would be if traditionally mounted in a wall dimmer application), its aluminum heatsink (maximum length: 58 mm; area: 3364 mm²; thickness: 1 mm) presents an 11 °C/W thermal resistor (refer to *Appendix F*).

The heatsink maximum temperature, in steady state (i.e. after more than 8 hours of continuous operation), reaches 108 °C for the maximum conduction time. This gives a maximum junction temperature of respectively 113 °C for the TS820 and lower than 111 °C for the STGF10NC60KD. The maximum average ambient temperature is then slightly higher than 60 °C (67 °C is measured inside the box at the top, whereas 57 °C is measured at the bottom).

Values measured for a 110 V rms line voltage are given in *Appendix E*.

2.8 Standby losses

Standby losses are mainly due to MCU consumption. For the STM8S103F2, using halt mode (low consumption MCU mode) the maximum current consumption at 125 °C is 105 uA (see SMT8S datasheet).

The quiescent current of the 5 V voltage regulator (U2) must also to be taken into account (typically 100 µA).

The dimmer standby loss for a 0.2 mA power supply output current, is 0.29 W at 230 V rms.

Note: This dimmer is not subject to standby directives as the board does not feature any display or sensors to automatically exit from standby mode ("wakeup" is initiated by the end-user by pushing a button).

2.9 Voltage surges

Thanks to the RV1 and RV2 varistors, the board is immune to voltage surges up to 2 kV when the dimmer is in the off-state.

When the dimmer is in the on-state, the SCR features a high current capability which renders capable of withstanding a surge current coming from a 2 kV surge, as described in the IEC 61000-4-5 standard.

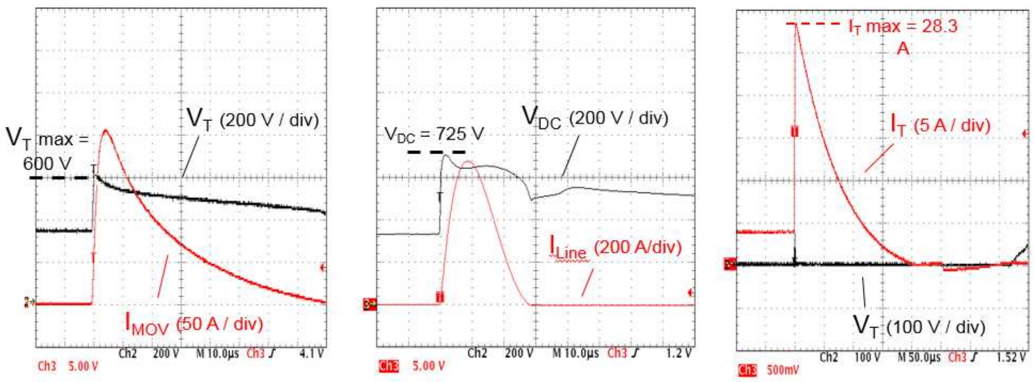
The waveforms that follow show the dimmer behavior in case of voltage surges.

For this test, a 2 kV voltage surge is applied on the peak mains voltage. The dimmer is placed in series with a 600 W - 230 V halogen lamp.

In *Figure 10*, left-side, the dimmer is in the off-state. In the 2-wire configuration, the 2 kV surge energy is absorbed by varistor RV1 which clamps the dimmer voltage to 600 V (equal to the maximum non-repetitive surge off-state voltage allowed for the SCR and the IGBT). In the 3-wire configuration, the surge is seen by the VIPer06 device (VDC). The surge voltage is clamped by the RV2 varistor below 800 V (VIPer06 maximum voltage capability), as seen in the second waveform.

In the last case, the dimmer is in the on-state when the 2 kV voltage surge is applied. Thanks to the high overcurrent capability of the TS820-600FP, the 8/20 µs current surge is absorbed by the SCR with no damage, even after having applied the 2 kV positive surge and 2 kV negative surges 10 times each.

Figure 10. IEC 61000-4-5 board performance



Dimmer OFF: 2-wire configuration SCR & IGBT remain OFF

Dimmer OFF: 3-wire configuration V_{DC} is below the VIPer maximum voltage (800 V)

Dimmer ON: SCR sustains the 8/20 current surge

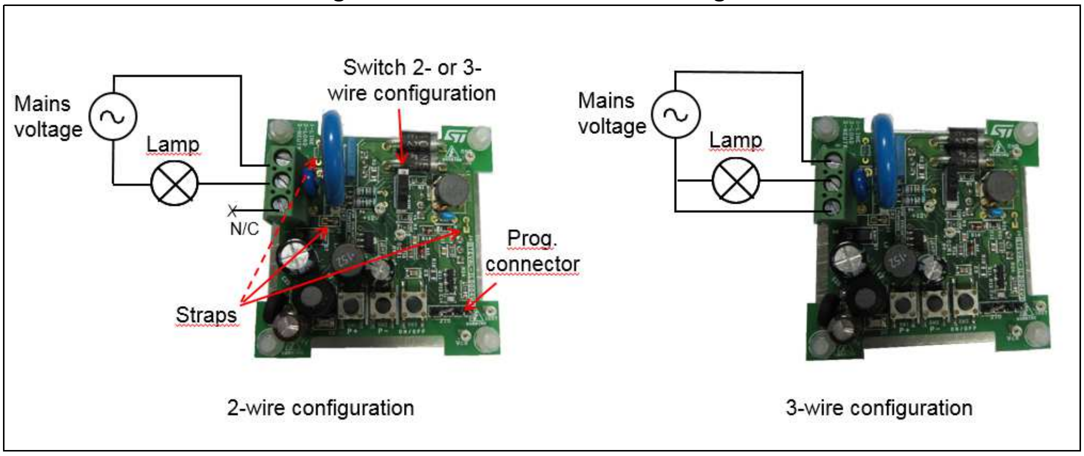
3 Getting started

3.1 Board connection and options

Figure 11 shows the connection diagram of the board (please refer to *Section 3.3* before performing any tests):

- SW4 switch: 2- or 3-wire configuration switch
- Header J11 is used to connect the dimmer to the mains and the lamp
  - See *Section 2.1* for the difference between both connection configurations
  - The appropriate connection of the lamp to the mains neutral or line will depend on electrical safety regulations. Normally, the lamp must be connected to neutral.
- The J10 connector is a 4-pin connector used to connect an MCU programmer (example: STM8S Discovery Kit) for software upload or inboard debugging.
- Several straps allow the user to add some optional components:
  - Strap 1: this strap can be used to add a thermal fuse.
  - Strap 2: this strap can be replaced by an inductor if an EMI passive filter is preferred to an IGBT. IGBT Q3 must then be disconnected by removing strap 3 for EMI evaluation and C15 input capacitor should be increased, particularly if compliance with EN55105 is expected.
  - Strap 3: this must be removed to disconnect the IGBT, as explained just above.

Figure 11. Board connection diagram

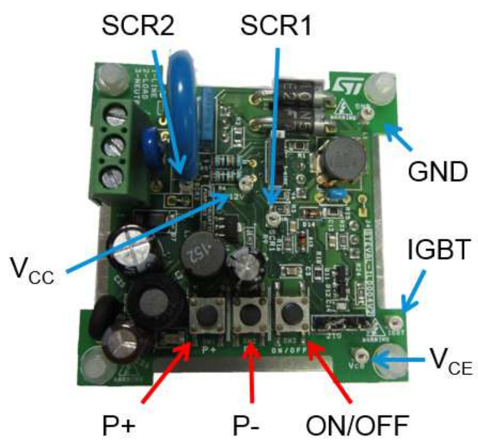


3.2 User interface

Figure 12 shows the user interface pushbuttons and measurement points:

- **ON/OFF** pushbutton: this button is used to turn on or turn off the dimmer.
- **P+** pushbutton: brief pressure (> 100 ms for 50 Hz operation) on this button produces an increase in lamp light of one step. Longer pressure allows the changing of the power level continuously.
- **P-** pushbutton: brief pressure (> 100 ms for 50 Hz operation) on this button produces a decrease in lamp light of one step. Longer pressure allows the changing of the power level continuously.
- **SC** LED: when on, this LED indicates that a short-circuit has been detected four times consecutively. The whole board will remain off up to line disconnection and reconnection.
- 2- or 3-wire switch: used to change dimmer configuration (refer to *Section 2.1*.)

Figure 12. User interface and test points (in blue)



3.3 Safety instructions

Warning: The high voltage levels used to operate the SCR dimmer evaluation board could present a serious electrical shock hazard. This evaluation board must be used in a suitable laboratory by qualified personnel only, familiar with the installation, use, and maintenance of electrical power systems.

The STEVAL-ILD004V2 evaluation board is designed for demonstration purposes only, and must not be used either for domestic or industrial installation.

3.4 Test procedure and test points

Follow this procedure to use the STEVAL-ILD004V2 board:

1. Connect the board either in 2-wire or in 3-wire configuration as explained in *Section 3.1: Board connection and options*
2. Turn the mains voltage on.
3. Press the on button to switch on the lamp. Take care to use a non-conductive tool to press each pushbutton in order to avoid contact with live parts, which are under line voltage.
4. Press the P+ and P- buttons, again using a non-conductive tool, to change the lamp brightness.

Using specific connectors (*Figure 12*), it is possible to measure several electrical signals:

- IGBT: IGBT gate command (MCU output)
- SCR1 and SCR2: respectively, Q1 and Q2 gate commands (MCU output)
- V_{CE}: IGBT collector terminal, to measure collector-emitter voltage if voltage probe is connected to GND
- V_{CC}: DC power supply voltage for IGBT gate drive (12 V)
- GND: board control reference; all previous voltages must be measured referenced to this GND connector

Please note that the STEVAL-ILD004V2 board is not insulated from the mains voltage. All test or measurement equipment should thus to be insulated from the mains to avoid line short-circuit though the equipment ground circuit. Also, as soon as a measurement ground is connected to the board, the equipment ground can be connected to the line voltage and may cause electrical shock if proper test procedures are not applied.

3.5 Possible changes

The following modifications can be applied by the end user if needed:

- Implement an EMI filter instead of an IGBT for EMC conducted noise fulfillment. The board schematic of the dimmer would then be greatly simplified (refer to *Appendix G*). To evaluate this solution, follow this procedure: Using strap 2, an inductor can be added and the C15 X2 capacitor can be changed. For example, for a 300 W US dimmer, a 29 µH inductor and a 100 nF capacitor can be used. For a 500 W European dimmer, a 2.4 mH inductor and a 100 nF capacitor can be used to fulfill EN55015 standards. Strap 3 must be removed in this case to disconnect the IGBT collector.
- The IGBT gate resistor, used to control the turn-on speed (R3), can be changed to obtain a different loss/noise trade-off. This can be done if a load power other than 600 W, 230 V is targeted, or if EN55015 does not need to be fulfilled.

If the J2 connector is used to upload the MCU software, the board must be disconnected from the mains before connecting the programmer.

3.6 Issue solving

If the LED is lit and the board does not respond to pushbutton pressure, this indicates that a short-circuit has been detected. You should restart the dimmer. Disconnect it from the mains, wait a few minutes to allow the V_{DD} level (5 V) decrease to below at least 2.5 V, and reconnect it with a new load before restarting the dimmer.

4 Conclusion

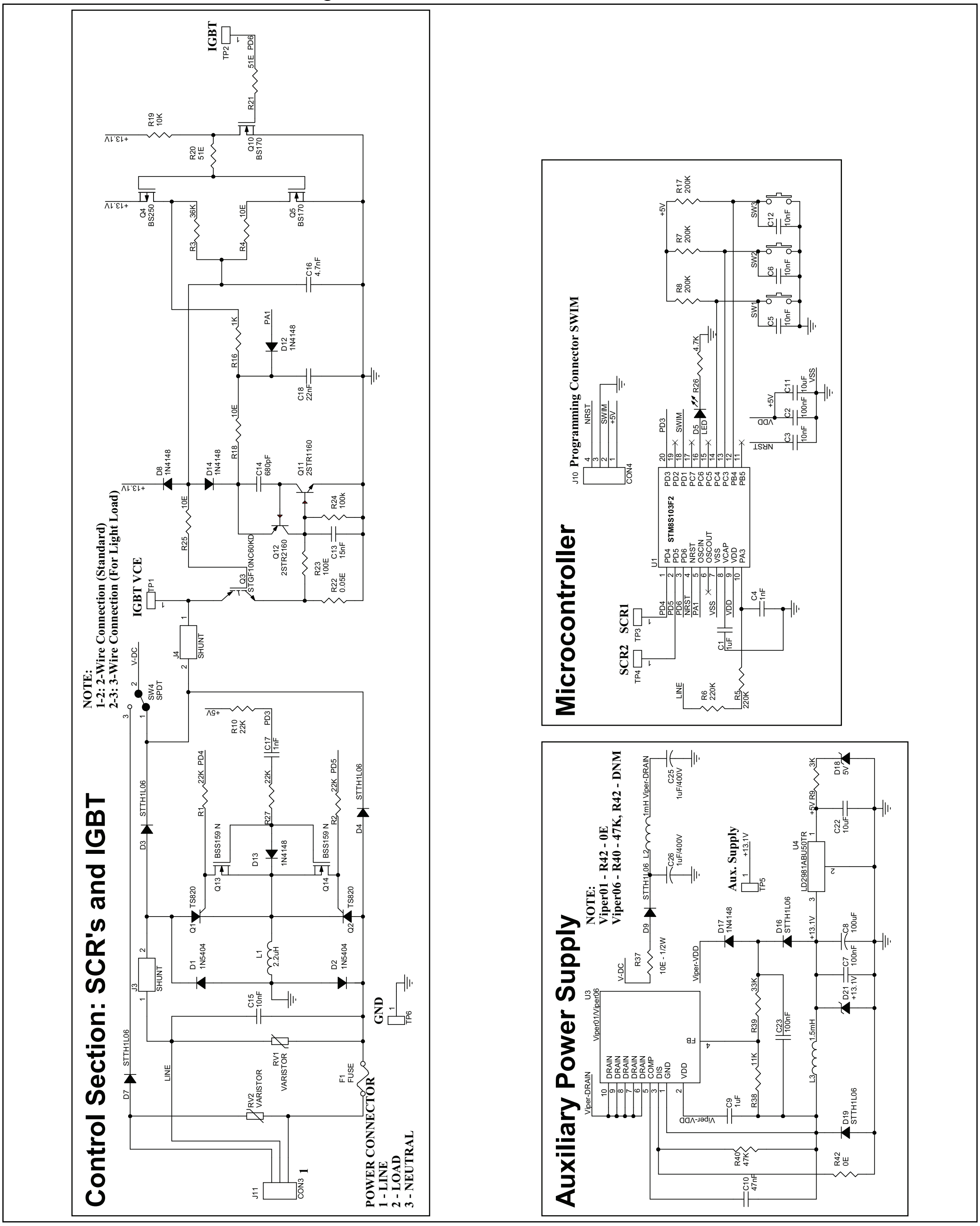
The STEVAL-ILD004V2 evaluation board allows designers to implement a leading-edge light dimmer which will be directly compliant with market requirements.

These requirements are:

- Dim all types of dimmable lamps:
  - From 3 to 600 W, 230 V power loads (or 300 W for 110 V)
  - Halogen, CFL, LED and transformer (magnetic or electronic)
- Compliant with European EMC standards:
  - EN55015: Limits and methods of measurement of radio disturbance characteristics of electrical lighting and similar equipment
  - IEC61000-4-4: Testing and measurement techniques – electrical fast transient/burst immunity test
  - IEC61000-4-5: Testing and measurement techniques – surge immunity test
- Smart interface:
  - Soft-start and soft-stop
  - Setting memory
  - Protection against load short-circuit due to connection error
- Possibility to adapt the dimmer to 2-wire or 3-wire operating mode:
  - fit all electrical wall dimmer installations
  - improved compatibility of the dimmer with a wider range of lamps

Appendix A Dimmer schematic diagrams

Figure 13. Dimmer circuit schematics



Appendix B Board layout and silkscreen

Figure 14. Component layout

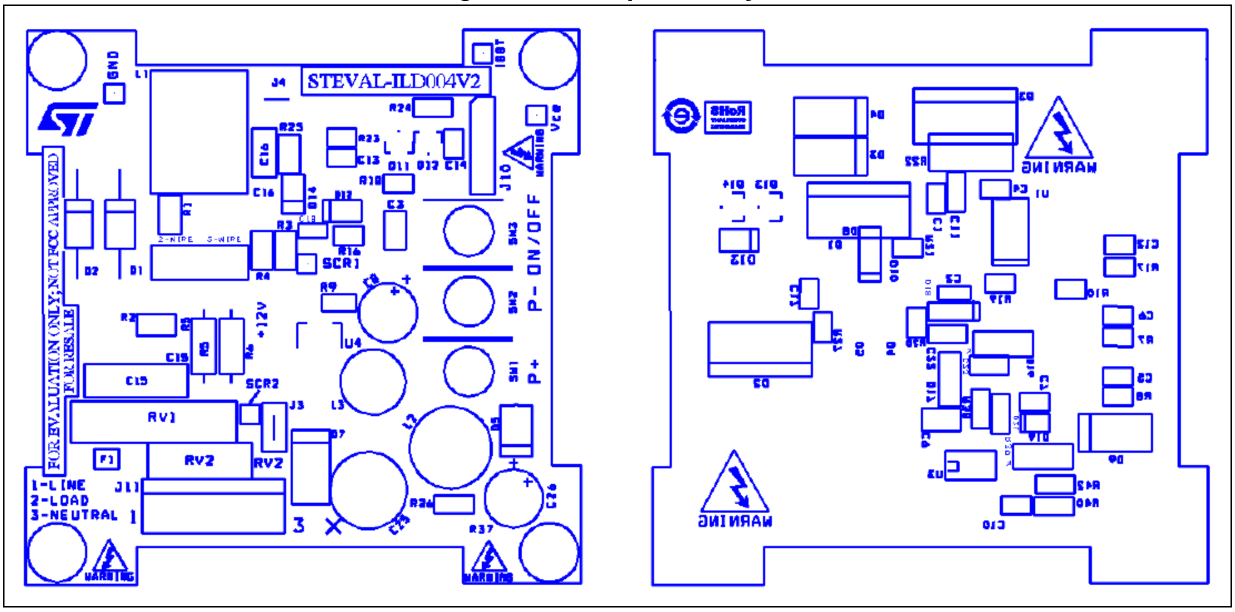
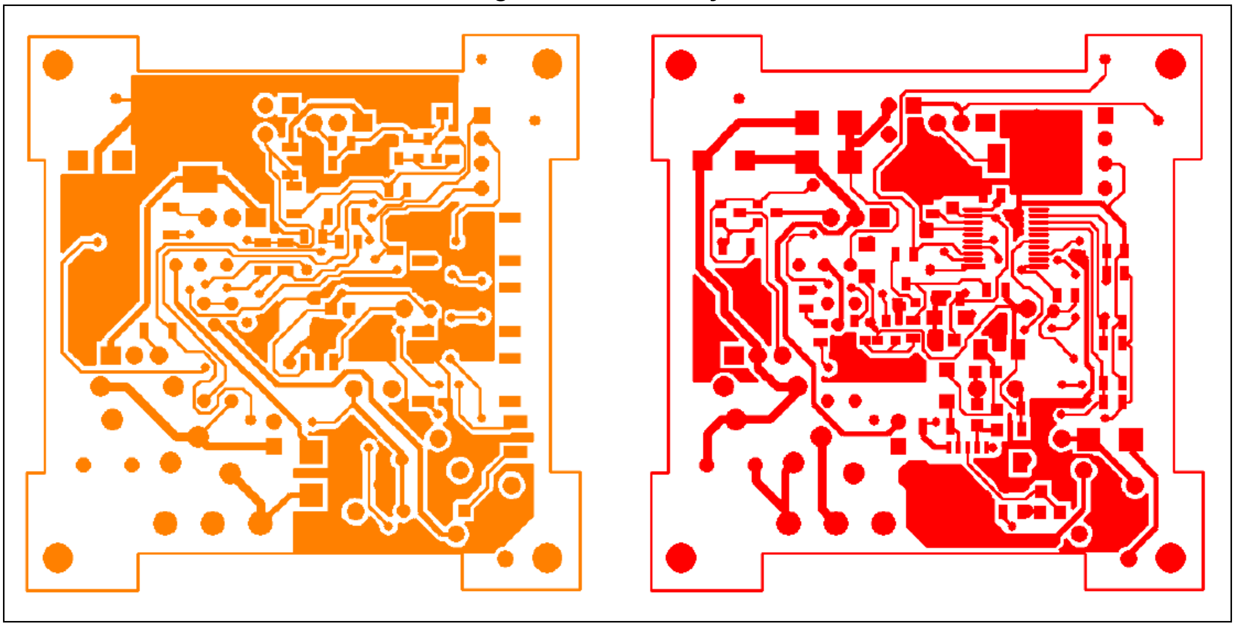


Figure 15. Board layout



Appendix C Bill of materials

Figure 16. Bill of material (BOM)

Item	Quantity	Reference	Part / Value	Voltage / Watt / Ampere
1	2	Q1,Q2	TS820	
2	1	Q3	STGF10NC60KD	
3	1	U1	STM8S103F2	
4	1	U3	Viper01/Viper06	
5	1	U4	LD2981ABU50TR	
6	1	Q11	2STR1160	
7	1	Q12	2STR2160	
8	6	D3,D4,D7,D9,D16,D19	STTH1L06	
9	1	Q4	BS250	
10	2	Q5,Q10	BS170	
11	2	Q13,Q14	BSS159 N	
12	1	L1	2.2uH	6.5A
13	1	L2	1mH	300mA
14	1	L3	1.5mH	380mA
15	1	C1	1uF	16V
16	1	C9	1uF	50V
17	3	C2,C7,C23	100nF	50V
18	1	C15	10nF	400V
19	4	C3,C5,C6,C12	10nF	16V
20	2	C4,C17	1nF	16V
21	1	C8	100uF	35V
22	1	C10	47nF	25V
23	2	C11,C22	10uF	16V
24	1	C13	15nF	16V
25	1	C14	680pF	35V
26	1	C16	4.7nF	50V
27	1	C18	22nF	50V
28	2	C25,C26	1uF	400V
29	4	R1,R2,R10,R27	22K	
30	1	R3	36K	
31	3	R4,R18,R25	10E	
32	2	R5,R6	220K	1/4 Watt
33	3	R7,R8,R17	200K	
34	1	R9	3K	
35	1	R16	1K	
36	1	R19	10K	
37	2	R20,R21	51E	
38	1	R22	0.05E	1W
39	1	R23	100E	
40	1	R24	100K	
41	1	R26	4.7K	
42	1	R37	10E - 1/2W	
43	1	R38	11K	
44	1	R39	33K	
45	1	R40	47K	
46	1	R42	0E	
47	2	D1,D2	1N5404	3A,400V
48	1	D5	LED	Red Color
49	5	D8,D12,D13,D14,D17	1N4148	
50	1	D18	5V	250mW
51	1	D21	+13.1V	250mW
52	3	SW1,SW2,SW3	SW_PB_SPST	
53	1	SW4	SPDT	
54	1	RV1	VARISTOR	300V, 20mm Dia
55	1	RV2	VARISTOR	300V, 7mm Dia
56	1	F1	FUSE	
57	2	J3,J4	SHUNT	
58	1	J10	CON4	SWIM Connector
59	1	J11	CON3	300V, 6A Power Connector
60	6	TP1,TP2,TP3,TP4,TP5,TP6	TEST POINT	
61	1	Heat Sink with mounting screws	Heat Sink	1mm Thick Aluminium Sheet

Appendix D Dimmer phase angle table

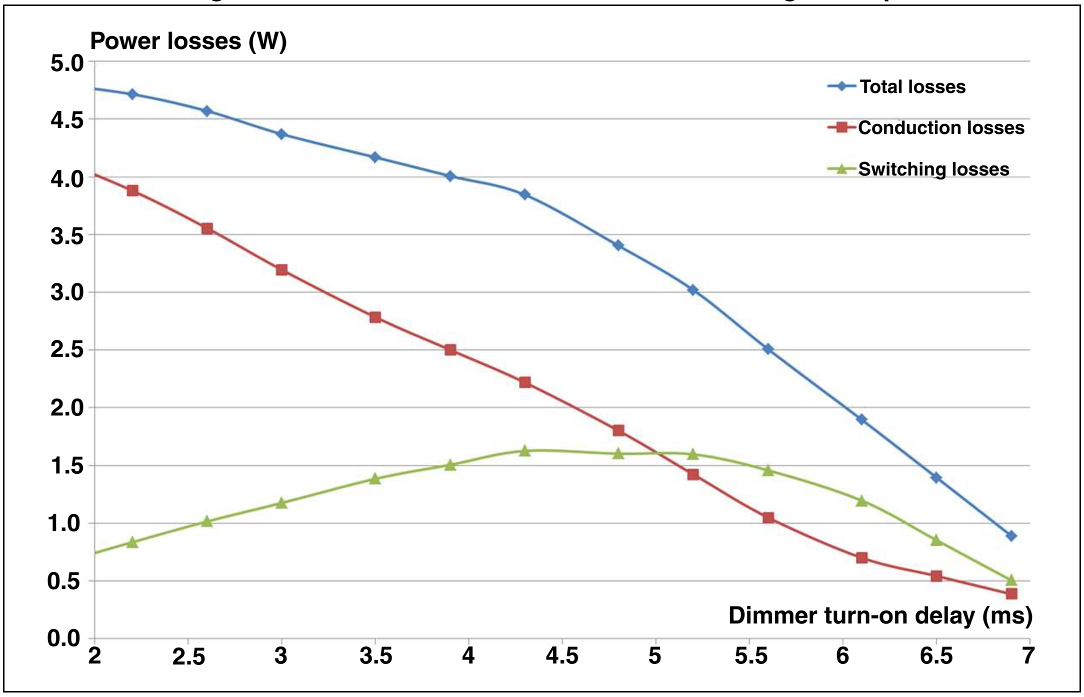
Figure 17. Dimmer phase angle table

Angle Number	Angle (°)	50 Hz delay (ms)	60 Hz delay (ms)
1	36	2	1.7
2	41.6	2.3	2
3	47.2	2.6	2.2
4	52.8	3	2.5
5	58.4	3.3	2.8
6	64	3.6	3
7	69.6	4	3.3
8	75.2	4.2	3.6
9	80.8	4.6	3.9
10	86.4	4.9	4.1
11	92	5.2	4.4
12	97.6	5.5	4.7
13	103.2	5.8	5
14	108.8	6.2	5.2
15	114.4	6.5	5.5
16	120	6.8	5.7
17	125.6	7.1	6
18	131.2	7.4	6.3
19	136.8	7.8	6.6
20	144	8	6.9

Appendix E Power losses and temperatures for a 300 W, 110 V load

Figure 18 shows the different power losses measured with a 300 W, 110 V halogen lamp, with the same IGBT gate circuit designed to fulfill the EN55015 standard (see *Section 2.4: Conducted noise*).

Figure 18. Power losses for a 300 W, 110 V halogen lamp



Maximum power losses are reached for the maximum conduction time and are equal to 4.7 W. These power losses are then slightly higher than those measured for the 600 W, 230 V load (4.5 W). Tests similar to those in *Section 2.7: Power losses* can be performed in a closed box environment. The junction temperatures of both the SCR and the IGBT will here again remain below the maximum allowed limits.

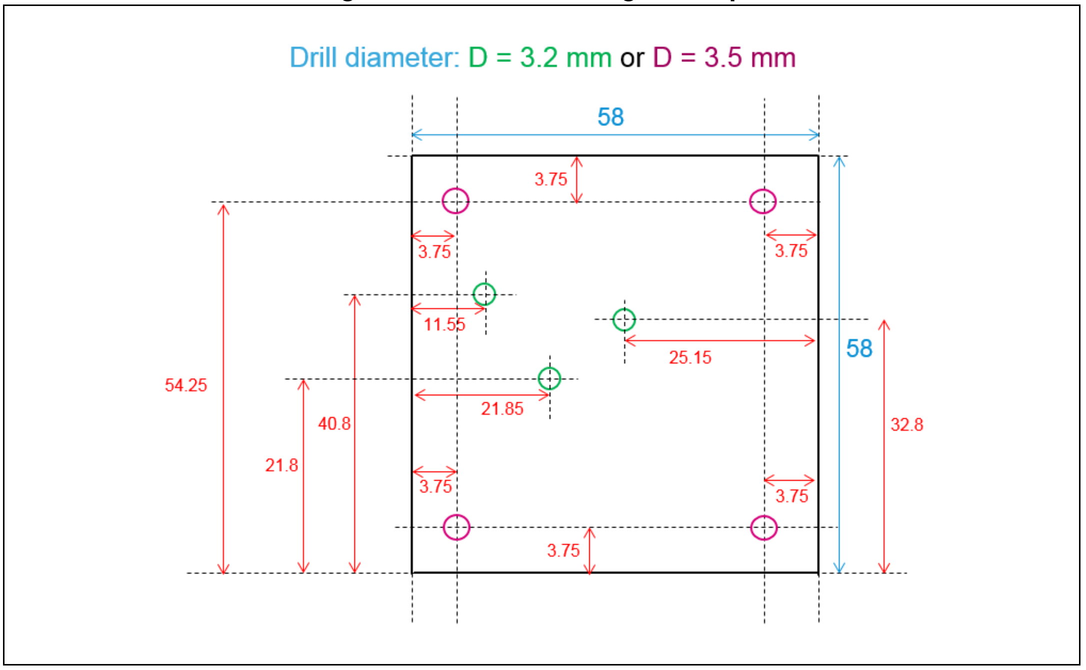
It should be noted that for the North American market, compliance to EN55015 is not mandatory. Therefore the IGBT gate resistance (R3) or capacitor (C16) can be reduced to reduce switching losses. It should be noted also that setting these values to a value that is too low could produce acoustic noise due to the mechanical oscillations of the tungsten lamp filaments.

Appendix F Heatsink design example (R_{th} = 11 °C/W)

Figure 19 shows the package outline of the heatsink used in the STEVAL-ILD004V2 board. The heatsink is manufactured with a 1 mm thick aluminum plate. Its thermal resistor is typically 11 °C/W.

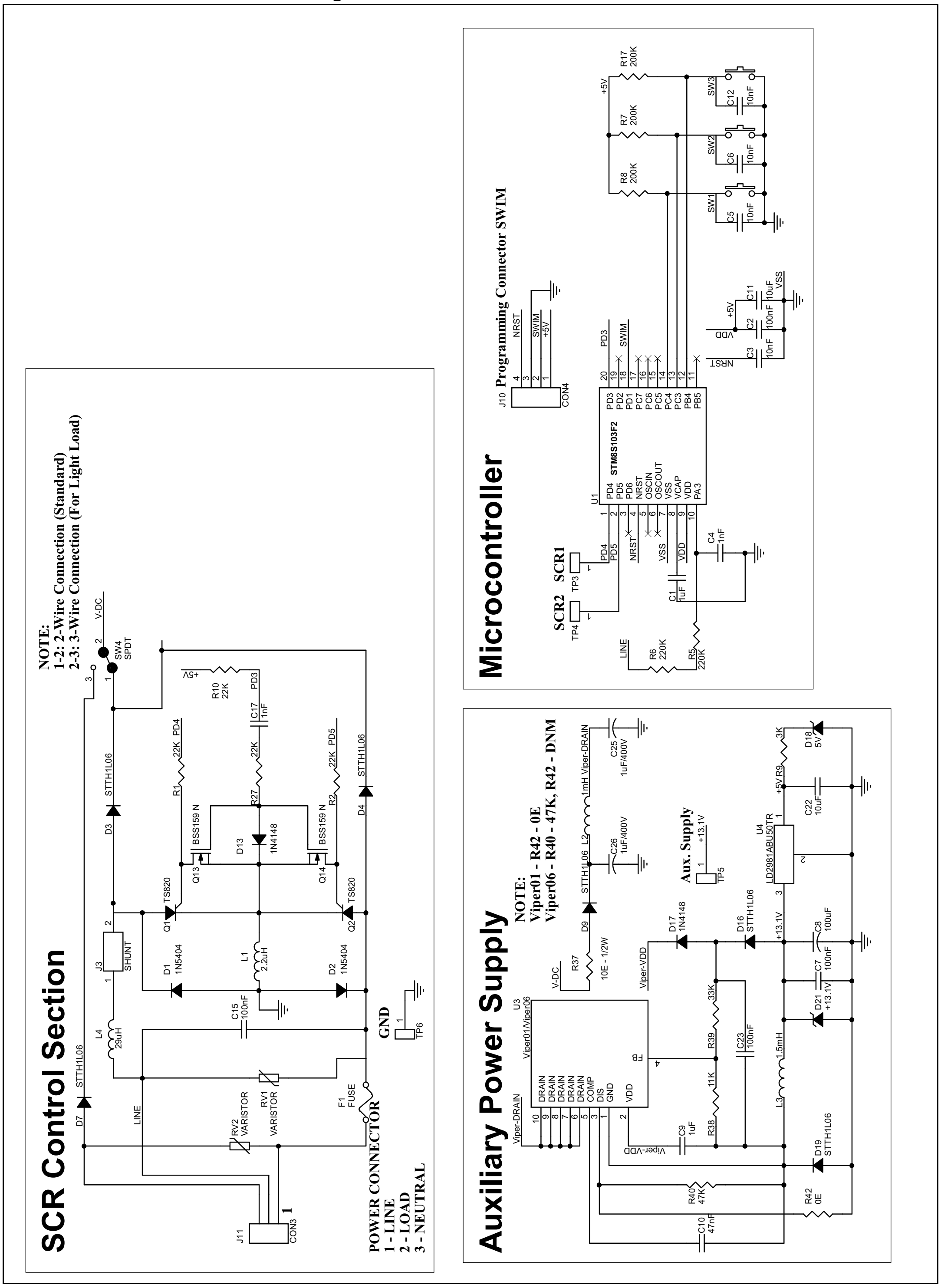
Dimensions are given in millimeters.

Figure 19. Heatsink design exemple



Appendix G Dimmer schematic without IGBT (L-C filter values given for 300 W - 120 V dimmer)

Figure 20. Dimmer schematic



Appendix H List of lamps compatible with the STEVAL-ILD004V2 light dimmer

Table 2. Lamps compatible with the STEVAL-ILD004V2

Lamp type	Manufacturer	Reference	Power
Magnetic transformer	ELLE PI.	DTR 105TF	150 VA
Electronic transformer	OSRAM	HalotronicHTM105	35 W / 230 V
CFL lamps	GOVENA	DIMM20W	20 W / 230 V
	MEGAMAN	SLU111d	11 W / 230 V
LED lamps	KAOYI	N/A	7 W / 230 V
	PHILIPS	Master 8E27A60	8 W / 230 V
	LEXMAN	POWERLED	10 W / 230 V
	LEXMAN	POWERLED	14 W / 230 V
	LED LIGHT	N/A	12 W / 230 V
	LumiHome	LED3WF14-P	3 W / 230 V
	OSRAM	Parathom	12 W / 230 V
	OSRAM	LED SUPERSTAR PAR16	4.8 W / 230 V
	TOSHIBA	LDAC06227E7EUD	6 W / 230 V
	Ecosmart	400674	13 W / 120 V
	Ecosmart	409440	15 W / 120 V
	PHILIPS	9E26A19DCAAAA	8 W / 120 V
	PHILIPS	EnduraLed 7E86PAR20D-I	7 W / 120 V
	TOSHIBA	827NFL23	16.3 W / 120 V
	PANASONIC	LDA8L-A1/D	7.6 W / 120 V
	SHARP	DL-LA6BL	9.6 W / 120 V
	TOSHIBA	LE_AWN4N/D	4.5 W / 120 V
	Mistubishi Parathom	LDA11-H-D	11.2 W / 120 V
	Hitachi	LDA7D/D	6.6 W / 120 V
	GE	65386	9 W / 120 V
	Sylvania	LED8PAR20	8 W / 120 V
	LSG	DFN-30-NW-NFL-120	15 W / 120 V
	LSG	DFN-38-NW-NFL-120	18 W / 120 V

Revision history

Table 3. Document revision history

Date	Revision	Changes
24-Mar-2016	1	Initial release.

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