UM0399
Application note

Vacuum cleaner evaluation board
STEVAL-IHM013V1

Introduction

This document provides details of the vacuum cleaner evaluation board, including jumper settings, load connections, and device and software features. In terms of both hardware and software, the tool is ready for use in the development of universal motor driving based on phase angle control.

This board implements a traditional design solution for a universal motor control circuit with a microcontroller as a driver. The STEVAL-IHM013V1 has been customized for vacuum cleaner applications, however it can be easily adapted for most home appliance or industrial applications based on phase angle control without speed closed loop control.

The electronic driver with TRIAC and microcontroller presented in this document is cost-effective and easy for designers to implement. Analog solutions are being progressively replaced by microcontroller designs even in low-cost applications. This evolution is primarily due to the possibility of implementing a soft-start function which allows the equipment to fulfill IEC 61000-3-3 standard on inrush currents. Their advantages also include flexibility, using less external components and easy adaptation by simple software modifications.

Contents

List of figures

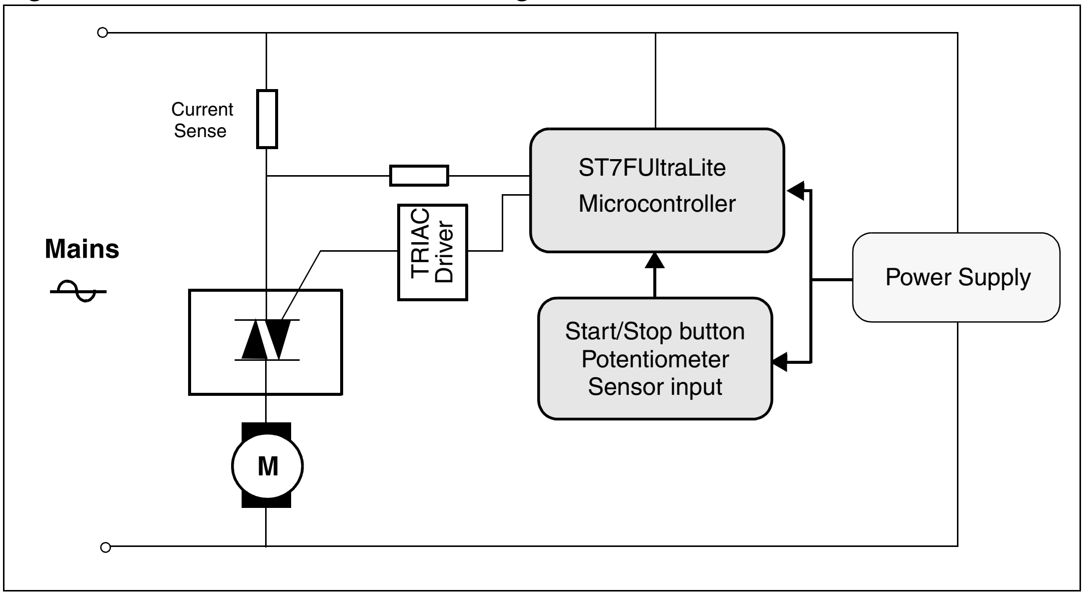
1 Overview

A universal motor can be driven in AC mode. *Figure 1* shows a typical block diagram for this variable speed drive principle. The goal is to adjust the motor voltage by varying the firing delay of a TRIAC. This is done with a very small and cheaper 8-bit microcontroller, the ST7UltraLite which allows for a greater range of high-performance features to be added.

The ST7UltraLite detects the *zero crossing* after each period of the mains supply and sets the TRIAC switching time related to the potentiometer voltage. The total power delivered to the load depends on the times at which the TRIAC is turned on.

Due to the low-power consumption, a low-cost capacitive power supply is used.

Figure 1. STEVAL-IHM013V1 block diagram



1.1 Controller

The microcontroller is used as a flexible controller since the functionality of an analog IC is tied to its application and the designer is limited to fixed device functions. Here, a control signal can be generated to trigger the TRIAC with respect to the phase control operation and current protection can be provided through a current sensing resistor.

Main features implemented:

- Motor speed regulation system: Through the potentiometer, the firing angle delay of the TRIAC can be adjusted. In other words, the TRIAC is switched on after the mains voltage zero crossing (ZC event) with a delay between a minimum and a maximum degree (<180°). The current is supplied from the mains to the load for a part of each half mains period. The current starts flowing through the load as soon as the TRIAC is turned on and stops at the next TRIAC current zero crossing. The power fed to the load varies depending on the firing angle delay: the lower the angle, the higher the power.

Control is performed symmetrically, i.e. the firing angle is kept constant within a period of the mains voltage.

- Full Bag checking input: Hardware microcontroller resources are available to implement this function. The code has to be customized according to the used sensor.
- High current protection: When motor current reaches the maximum allowed peak current (I_{MAX}), the Controller disables the fire TRIAC routine (LED turns on and motor stops). The Controller waits for another Start (Start/Stop button) to run the motor (LED turns off).
- Sensing of the Mains frequency. At startup the microcontroller automatically recognizes the Mains frequency (50 Hz or 60 Hz).

In this evaluation board the ST7FUltraLite has been chosen in the SO-8 package, but it is still available in the DIP8 and DFN8 packages. Features include:

- Extended -40°C to 125°C temperature range
- Fast 10-bit ADC
- 8-bit timer with Watchdog, 12-bit ART, 6 I/Os
- External and internal clock management
- 5 power-saving modes including autowakeup from Halt

Note: The microcontroller has still one I/O-ADC PIN free for other use.

The free pin is connected to the strip line connector and is used as a *full bag sensor* input (see *Figure 2*). If a full bag sensor is present in the vacuum cleaner, it can be connected and used with a routine which handles a full bag event in the firmware.

1.2 TRIAC

Available either in through-hole or surface-mount packages, the BTAXX, BTBXX and TXX TRIAC series are suitable for general purpose AC switching. They can be used either for ON/OFF functionality (in applications such as static relays, heating regulation and induction motor starting circuits) or for phase control operation (in light dimmers and motor speed controllers). In the STEVAL-IHM013V1, the snubberless type of TRIAC has been chosen because they are specially recommended for use with inductive loads, due to their high commutation performance. The evaluation board has been tested with a 1400 W/230 V universal motor using a mounted BTB12-600BW. However it can be arranged for other kinds of motors up to 2000 W. *Table 1* provides an indication of the ST devices for the different vacuum cleaners. Refer to *Section 4: Application design procedure* to choose the suitable device for your application.

Table 1. TRIAC part number proposals for different vacuum cleaner powers

Mains voltage (V)	Vacuum cleaner power (W)	TRIAC [1] Part number
220-240V	1400-1600	BTB10-600BW / BTB12-600CW
	1600-1800	BTB12-600BW
	1800-2200	BTB16-600BW
100-120V	800-1000	BTB16-600BW
	1000-1200	BTB24-600BW

Note: 1 For new devices consult www.st.com

1.3 Power supply

To reduce board costs, a power supply with a capacitive power supply has been integrated (see *Figure 3*). The power supply circuit (using R9, C5, D1, D2 and C4) is developed to supply the microcontroller and TRIAC.

The upper level of this power supply is connected to the TRIAC drive reference (terminal A1). This allows the gate current to be sunk from the gate, In this way we can correctly trigger snubberless TRIACs (they can only be triggered in quadrants 1, 2 and 3 [AN437]).

2 STEVAL-IHM013V1 evaluation board

The STEVAL-IHM013V1 evaluation board was developed to demonstrate an ST solution for low-end vacuum cleaner applications but it can be a good starting point for designing any applications where there is a need to drive a universal motor. The board is shown in *Figure 2*.

On the upper side of the board there are two pairs of *faston* connectors:

- the mains connectors (Mains)
- the connector for the motor

On the right-hand side of the board can be found:

- **Speed adjustment potentiometer**

  The potentiometer emulates the standard vacuum cleaner control to regulate the power (motor speed).
- **ICC connector and jumper**

Warning: Before uploading firmware to the microcontroller, ensure that jumper J2 is NOT present before the input voltage is connected. It is also mandatory to supply the board with an external 5 V input through a DC power supply. Under normal conditions these jumpers must be present before the input voltage is connected.

With minimal adjustment, the STEVAL-IHM013V1 can drive motors from 1200 to 2000 W.

The maximum power range used on the evaluation board depends on both the motor (with its maximum handling current) and the TRIAC mounted on the board (see *Section 4: Application design procedure*).

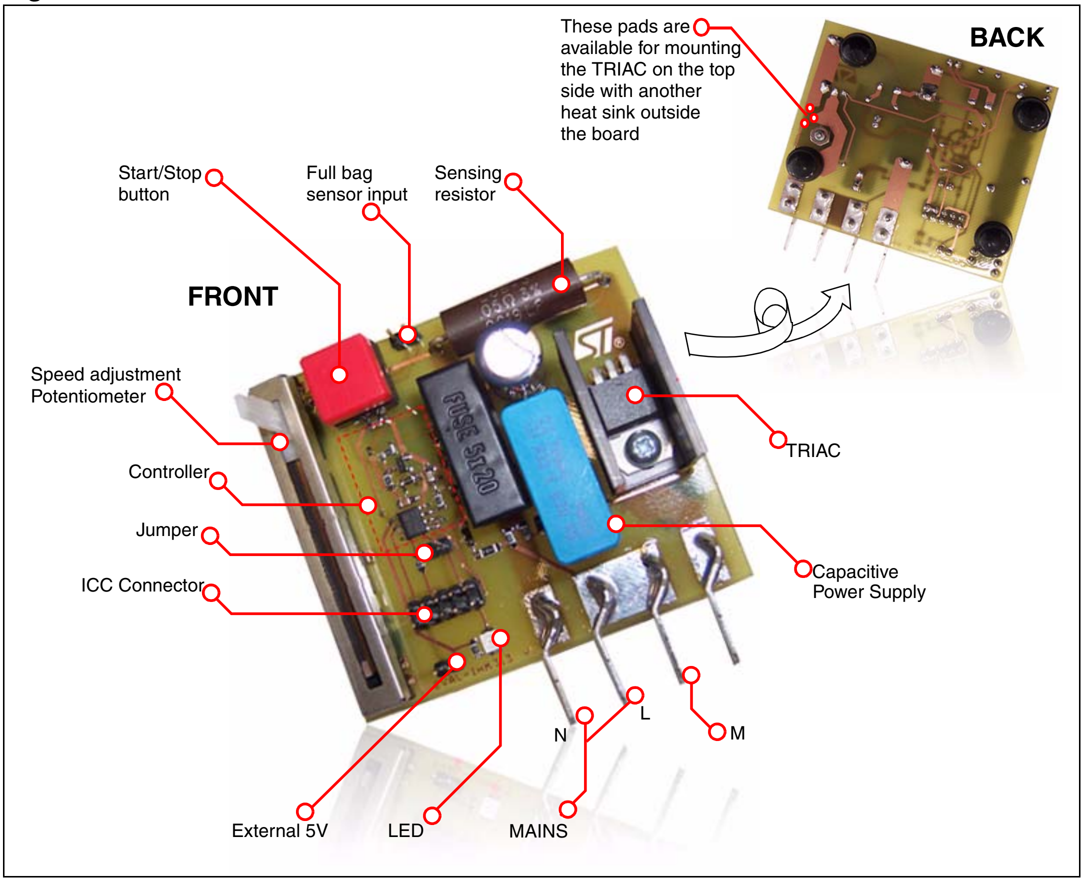
This evaluation board is configured to work with a 1400 W universal motor (230 V / 50 Hz).

Note: The capacitive power supply is not isolated from the AC line voltage.

- **Full Bag Checking input**

  Hardware microcontroller resources are available to implement this function. The code has to be customized according to the sensor used.

Figure 2. STEVAL-IHM013V1 evaluation board



3 Size optimization design procedure

The application is optimized for 1400 W vacuum cleaners (230 V/ 50 Hz).

The size of the board (see *Figure 2*) is small enough to be inserted directly in the appliance. It can be mounted on a dual layer standard PCB and all devices must be mounted on the top side to reduce the manufacturing cost.

To minimize the size of the board:

- The ICC connector is not needed in the manufacturing process because the microcontroller can already be programmed before assembling.
- The potentiometer emulates the power button of the vacuum cleaner and would normally be replaced by another multi-switch on the appliance.
- The board can be mounted near the motor where the air flow can be used to cool the components, so the size of the heat sink can be reduced.
- The UltraLite micro is available in a smaller DFN8 package (less than 16 mm^2).

With these adjustments the optimal design can be achieved.

4 Application design procedure

This evaluation board can be configured for different universal motors: 1200 - 2000 W, here we have an example of design procedure for 1400 W motor (230 / 50 Hz). If the user wants to configure the evaluation board for other motors, the following adjustments are necessary:

- Capacitive power supply
- Sensing resistor: R_{SENS}
- TRIAC driver
- TRIAC

4.1 Capacitive power supply

In order to have a constant voltage across capacitor C2, the average value of the input current (I_{in}) must be more than or equal to the average value of the output current (I_{out}) sunk by the board [AN1476].

Current through this capacitor (C2) flows during only the positive half cycle of the supply.

During the negative half cycle it flows through the Zener diode.

I_{in} is limited by R1 and the reactance of C1. The R1 resistor limits the inrush current, which must be lower than the maximum current through the capacitor C1. Input current (I_{in}) is a half-wave current, whose average value is given by:

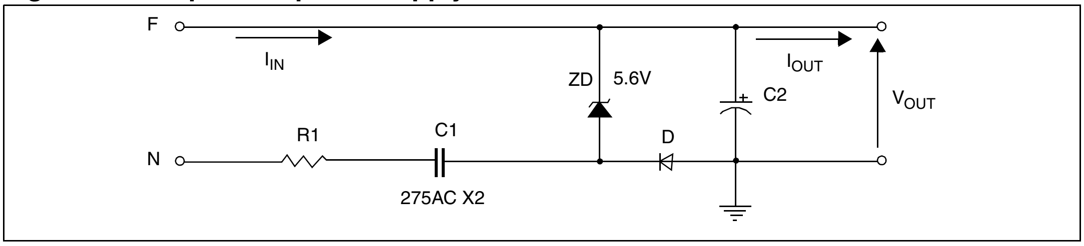
Equation 1

$$I_{in} = \frac{\sqrt{2}V_{RMS} - V_{ZD}}{\pi \cdot (X_{C1} + R_1)} = \frac{\sqrt{2}V_{RMS} - V_{ZD}}{\pi \cdot \left(\frac{1}{\omega C1} + R1\right)}$$

Where,

V_{RMS} = the RMS voltage, V, of an AC sine wave,
V_{ZD} = the voltage drop, V, across the Zener diode, and
X_{C1} = the reactance of the capacitor C1.

Figure 3. Capacitive power supply



The capacitor C2 reduces ripples from the output supply. As one tries to withdraw more and more current, the ripples increase. The high value of C2 would reduce the ripples from the supply up to a certain limit. The value of R1 should be such that V_{peak}/R1 is more than the current limit of the Zener.

The maximum average current sunk by the board is about 8 mA for 400 μsec gate current pulse widths.

Table 2. Maximum average current sunk by the board

Device	Average current consumption	Comments
MCU	4 mA	Average supply current in run & wait mode F_{CPU} = 8 MHZ V_{DD} = 5 V
Average current to drive the TRIAC	4 mA	The MCU drives the TRIAC through Q2. The average current is the sum of the current surge from Q2 and from TRIAC during the turn-on pulse. V_{DD} = 5 V, R_2 = 47 Ω±1%, R_5 = 2.7 kΩ±1% and T_P = 400 µsec
Red LED	1.4 mA	It is turned on when an overcurrent has occurred and the motor has stopped (TRIAC turned off).
Total	8 mA	The maximum current sunk of the board occurs in run mode. Triac turned on, red LED off.

To ensure the delivery of enough current in the worst conditions: (V_{peak}, f, C1 at minimum and R1 at maximum), the average output current, sunk by the board, must match the following conditions (minimum value of Main , f -10%, capacitor value has -10% accuracy and R1 value has -10%). For a 230 V / 50 Hz supply and neglecting the R1 the I_{in} in the worst conditions:

Equation 2

$$I_{inMIN} = \frac{\sqrt{2} \cdot \ 198 - 5.6}{\pi \cdot \left(\frac{1}{2\pi \cdot \ 49,\ 5 \cdot \ 0,\ 9 \cdot \ C_1}\right)}$$

Table 3 gives the maximum average current to be supplied in relation to the various AC capacitors.

Table 3. Maximum output DC average currents

AC Capacitor	Max. output average current for standard conditions	Max. output average current for worst case
220 nF	7.1 mA	5.4 mA
330 nF	10.5 mA	8.1 mA
470 nF	15 mA	11.5 mA
680 nF	21.7 mA	16.6 mA
1 µF	32 mA	24.5 mA

The maximum average current sunk by the board is about 8mA, so one capacitor of 330 nF (C5) and one flame proof resistor of 47 Ω / 1 W (R9) have been chosen. The output voltage is:

Equation 3

$$V_{out} = V_{ZD} - V_D = 5\ V$$

Refer to *Appendix A: Capacitor value according to country* in order to find how to configure the board versus different AC mains.

4.2 Sensing resistor (R_{SENS})

The value of the sensing resistor must be chosen to guarantee the right power dissipation at the maximum handling current and to guarantee at least 300 mV in order to read the motor current through the on board microcontroller 10bit ADC.

The evaluation board has been set and tested for a 1400 W motor (230 V/50 HZ) and a sensing resistor of 0.05 Ω/ 5 W is used. So the maximum handling current is 10A (2000 W universal motor).

Equation 4

$$R_{SENS} = \frac{0.05\ \Omega}{5\ W}$$

4.3 TRIAC

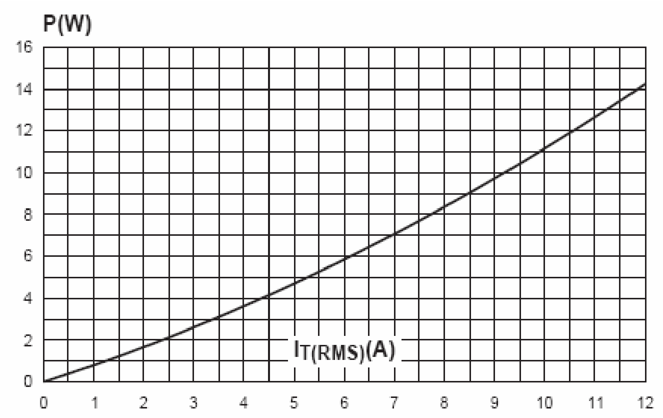
Calculating the maximum output power (maximum load) is one of the most important activities in this design, and the results depend mainly on the TRIAC being used. The current capability of this TRIAC limits the maximum output power. The design is versatile, so designers are able to choose the best TRIAC for producing the maximum output power for their applications.

The BTB12-600BW is a 12 A TRIAC with a heat sink built into this evaluation board that controls the power until 1800 W. For power requirements more than 1800 W or with the mains 110 V / 60 Hz the designer can refer to *Table 1*. These TRIACs are snubberless, so they do not need any other external snubber circuit as protection.

The current flowing through the TRIAC increases its temperature. When the current is too high, it is necessary to use a heat sink. We explain below how to select the right heat sink for a 1400 W motor.

The maximum power dissipation on the TRIAC versus the RMS ON state current (full cycle) is shown in *Figure 4*. The power dissipation on the TRIAC for 5 A of current, for example, is approximately 4.8 W.

Figure 4. Maximum power dissipation versus RMS on-state current (full cycle)



The formula to calculate the maximum thermal resistance between heat sink and ambient air is the following:

Equation 5

$$R_{th(h-a)} = \frac{T_j - T_a}{P} - R_{th(j-c)} - R_{th(c-h)}$$

Where:

T_j = the maximum junction temperature in °C

P = the maximum dissipated power in W

$R_{th(j\text{-}c)}$ = given in the TRIAC datasheet (°C/W)

$R_{th(c\text{-}h)}$ = given in the TRIAC datasheet (°C/W).

Equation 6

$$R_{th(h-a)} = \frac{125 - 40}{4.8} - 1.4 - 0.5 = 15.8\ °C/W$$

Note: This calculation is done for an ambient temperature of 40 °C and with the TRIAC that is on the evaluation board. The size of the heat sink can be dramatically decreased since the TRIAC is placed in the air flow of a vacuum cleaner which can cool it.

On the board a heat sink (R_{th} = 18 °C/W) is mounted as shown in *Figure 2* to have a compacted solution but if using another motor, another heat sink can be assembled outside the board. The size and specifications of this device can be chosen using these procedures and by consulting *Table 1*.

4.4 TRIAC driver

The TRIAC is driven via a bipolar transistor in order to guarantee proper operation across the entire extended temperature range using only one of the microcontroller's pins. In fact the triggering gate turn-on current needed is 50 mA in nominal conditions, but it increases up to 100 mA for a -20 °C junction temperature. In this case, in order to directly drive the TRIAC with the microcontroller, 3 HS I/O pins connected in parallel are required. On this board only two HS I/O pins are available and it is for this reason that a TRIAC driver stage (R3, R5, R6 and Q2) is chosen.

4.5 ZCD resistor calculations

In order to synchronize the opening of the TRIAC with the input sinusoidal voltage waveform in each period, the microcontroller must make the zero crossing detectable. Resistor R3, capacitor C3, and two internal clamping diodes (inside the microcontroller) provide this means of detection (see *Figure 14*).

The maximum voltage on the resistor R3 is 325 V (RMS voltage value is $230V_{ac}$) therefore, in order to limit the current in the microcontroller I/O pin, one metal film resistor of 330 KΩ - 0.6 W has been chosen.

5 Software

The software is written in C language. The development toolset used is SOFTEC STVD7. If any modification to the source files has been made, the project has to be rebuilt, thus generating a new *STEVAL_IHM013V1.s19* file. This file is used to program the microcontroller.

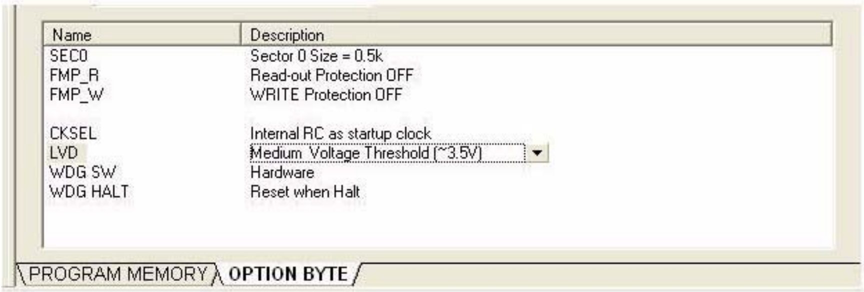
The main functions necessary for the proper operations of the evaluation board can be found in the following *.c* files:

- main.c,
- ports.c,
- pwm_ar_timer_12bit.c,
- trap.c,
- adc_8bit.c
- interrupt_vector.c

The option byte set in this project is shown in *Figure 5*.

Note: The overall code has less than 1KB so that it fits within the ST7UltraLite memory.

Figure 5. Option byte for STEVAL-IHM013V1 firmware



The working principle of using the TRIAC to drive a universal motor is usually to switch the TRIAC to ON at the exact time in both half-periods of the sine wave. The kind of control performed is then symmetric, i.e. the firing angle is kept constant within a period of the mains voltage. The minimum and maximum opening time for the TRIAC is set as a constant value by software and can be easily modified to guarantee the requested power range for different applications. The current is thus supplied from the mains to the load for a part of each half mains period. The current starts flowing through the load as soon as the TRIAC is turned on and is stopped at the next TRIAC current zero crossing. The power fed to the load varies depending on the firing angle delay: the lower the angle, the higher the power.

The main idea of the software is to synchronize the internal timer inside microcontroller ST7UltraLite with the Zero Crossing (ZC) events of the mains sinusoidal waveform. The voltage from the mains is applied on the PA2 pin which is set up as input interrupt in a pull-up configuration.

The 12-bit Auto-reload Timer (AT timer) is used in Output Compare (OC) mode. The AT timer overflows on address FFFh to the value set in Auto-reload (ATR), in this configuration, 000h.

For each interval of the ZC synchronized (sync) event (see *Figure 6*), the DCR register is filled by the actual counter state from CNTR + the value corresponding with the 0.2 ms interval (640 h). From that time, the ZC is synchronized on the mains.

After that, each 0.2 ms OC interrupt occurs, where DCR = DCR + the value corresponding with the 0.2 ms interval (640 h). Each OC interrupt increments the software counter (see *Figure 7*).

The main advantage of this is that the CNTR register is readable at any time and the new value can be written immediately to the DCR register without any delay. The 0.2 ms interval is the smallest step required for firing the TRIAC. The TRIAC is fired from pin PA4 through the TRIAC driver block. The Watchdog is used in hardware configuration (set up in the option bytes). The watchdog routine has been implemented to fulfill the IEC61000-4-4 standard on electrical fast transient burst tests [AN1015].

Figure 6. Phase angle control

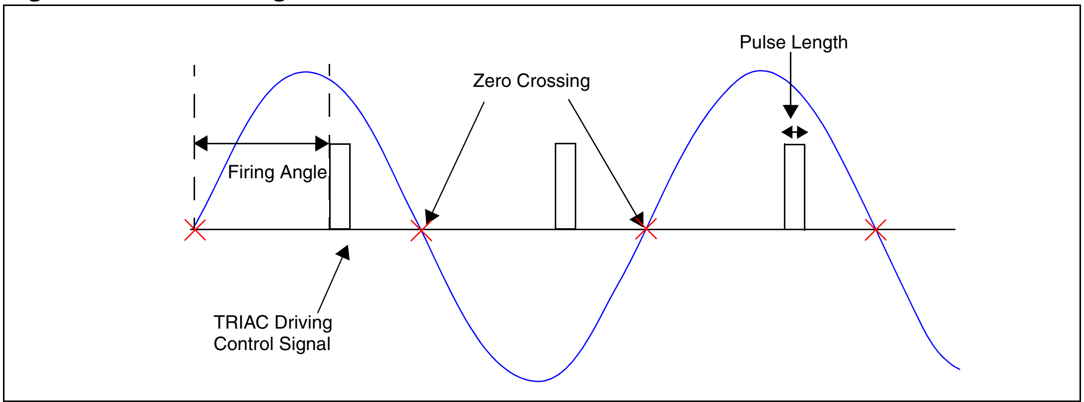
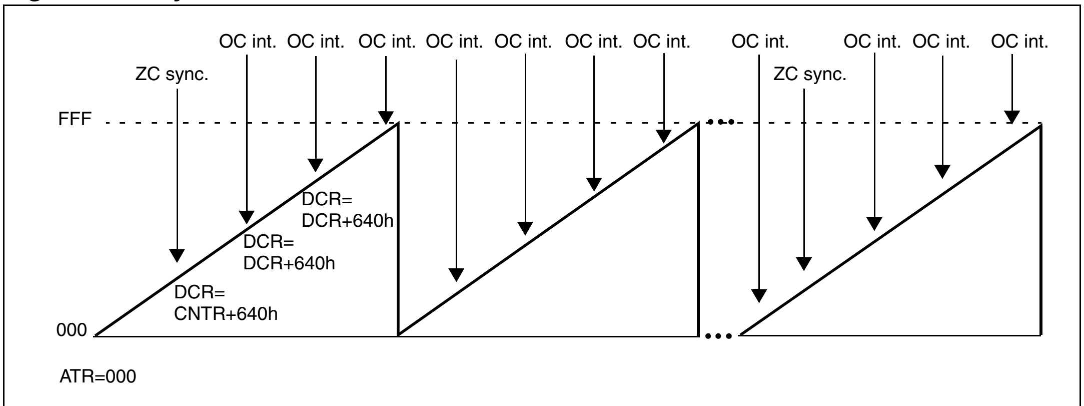


Figure 7. Synchronization



The designer must define the maximum peak current I_{MAX} the *lib.h* file. The default parameter is set at 20 A (for a 1400 W universal motor). If the motor is changed, it may be necessary to change this parameter to evaluate a maximum peak current at the startup.

For example, to calculate the value for 20 A, the maximum value readable in the $R_{sensing}$ is:

Equation 7

$$V_{MAX} = R_{sensing} \cdot 20 = 0.05 \cdot 20 = 1\text{ V}$$

The $R_{sensing}$ voltage ($V_{sensing}$) is equal to +5 V minus the read value on the PA5 pin (ADC channel 4). This can be used to calculate I_{MAX}:

Equation 8

$$I_{MAX} = \frac{5 - V_{MAX}}{5} \cdot 1024 = 819$$

So the designer must set:

```
#define I_MAX = 0x333
```

To improve the function of the current protection routine, the user can optimize the parameters of the soft start / variation routine:

SOFT_VAR_COUNTER: establishes the number of cycles of the Mains the fire angle will be read and updated.

SOFT_START_COUNTER: establishes the number of cycles of the Mains the fire angle will be kept to a minimum at startup.

These values have to be chosen and customized according to the electric specs of the motor (i.e. maximum current at startup). In this way we can avoid unexpected overcurrent events at startup.

These parameters are set for a 1400 W universal motor:

```
#define SOFT_VAR_COUNTER 6
#define SOFT_START_COUNTER 25
```

Using the parameter TP_DURATION the duration of the gate current pulse of 200 µsec (1) or 400 µsec (2) can be chosen. This parameter is set to:

```
# define TP_DURATION 2
```

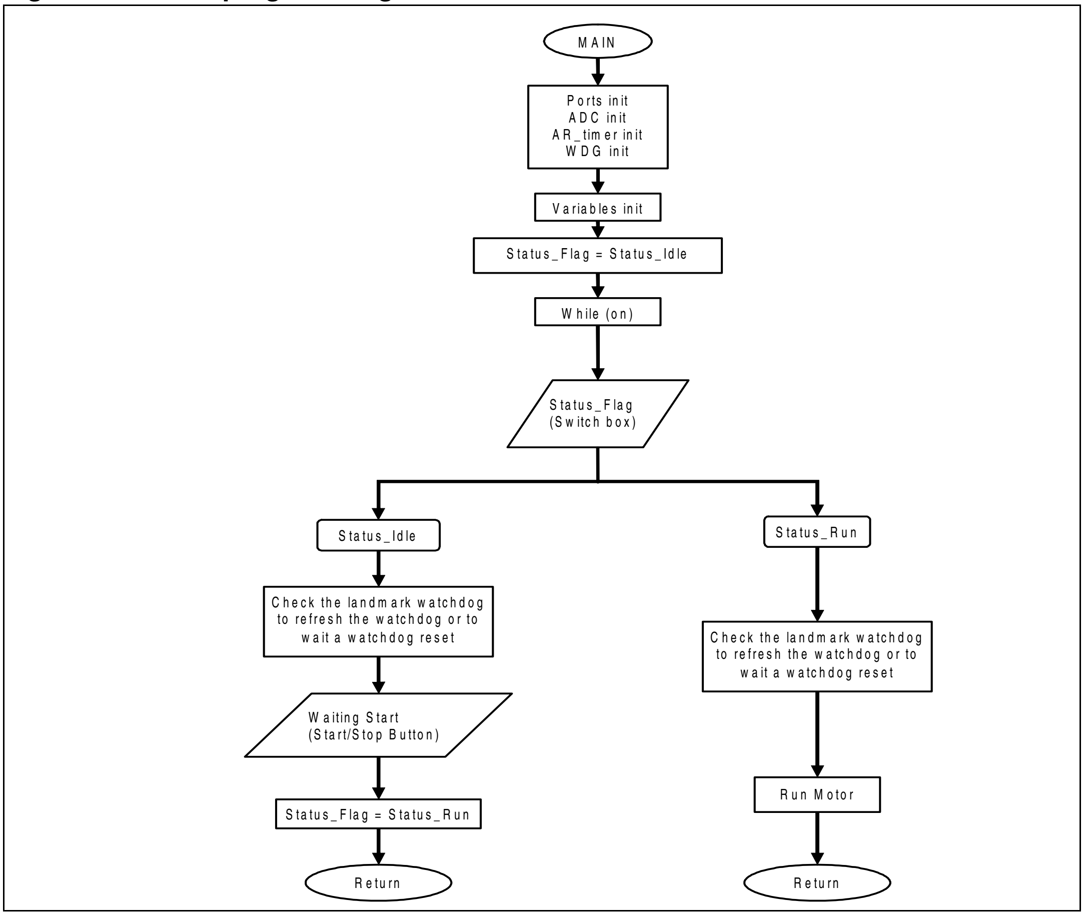
Note: When uploading the firmware to the microcontroller, J2 jumper must NOT be present when the input voltage is connected. However, in normal conditions these jumpers must be present before the input voltage is connected. See Figure 2.

5.1 Main.c

After the MCU is turned ON, all peripherals in use (e.g., ports, LITE Timer, and 12-bit autoreload), plus the ADC and Watchdog refresh (WDG) are set up in the "Main" program. After this, all variables are configured and the MCU goes into the state machine routine, where the state variable is Status_flag (see *Figure 8*). The first state is Status_Idle where the micro waits a start through start/stop button and then goes into Run state. In this state the program follows the routines according to hardware and software events (ZC synchronization and the OC timer).

The process goes into the idle state (motor stops) if a push button has been pushed or if there was an overcurrent read from the high current protection routine (the LED will be turned on until another start on the push button). The program then returns to the idle state (see *Figure 8*).

Figure 8. Main programming flowchart



5.2 ports.c

All timers are switched off until the first ZC event occurs. This interrupt is handled in the *ports.c* file by the PORTS_2_Interrupt routine (see *Figure 9*) which checks the PA2 pin on the falling edge. This pin is set up as the input interrupt in pull-up configuration. After catching the first interrupt, the AT timer is switched ON and the DRC is loaded with the 0.2ms value for the compare interrupt. The timer is then synchronized with the ZC event. The ZC window is set up for 50 Hz and the interrupt routine finishes. From this point, the AR_TIMER_OC_Interrupt routine is performed every 0.2 ms (see *Figure 10*).

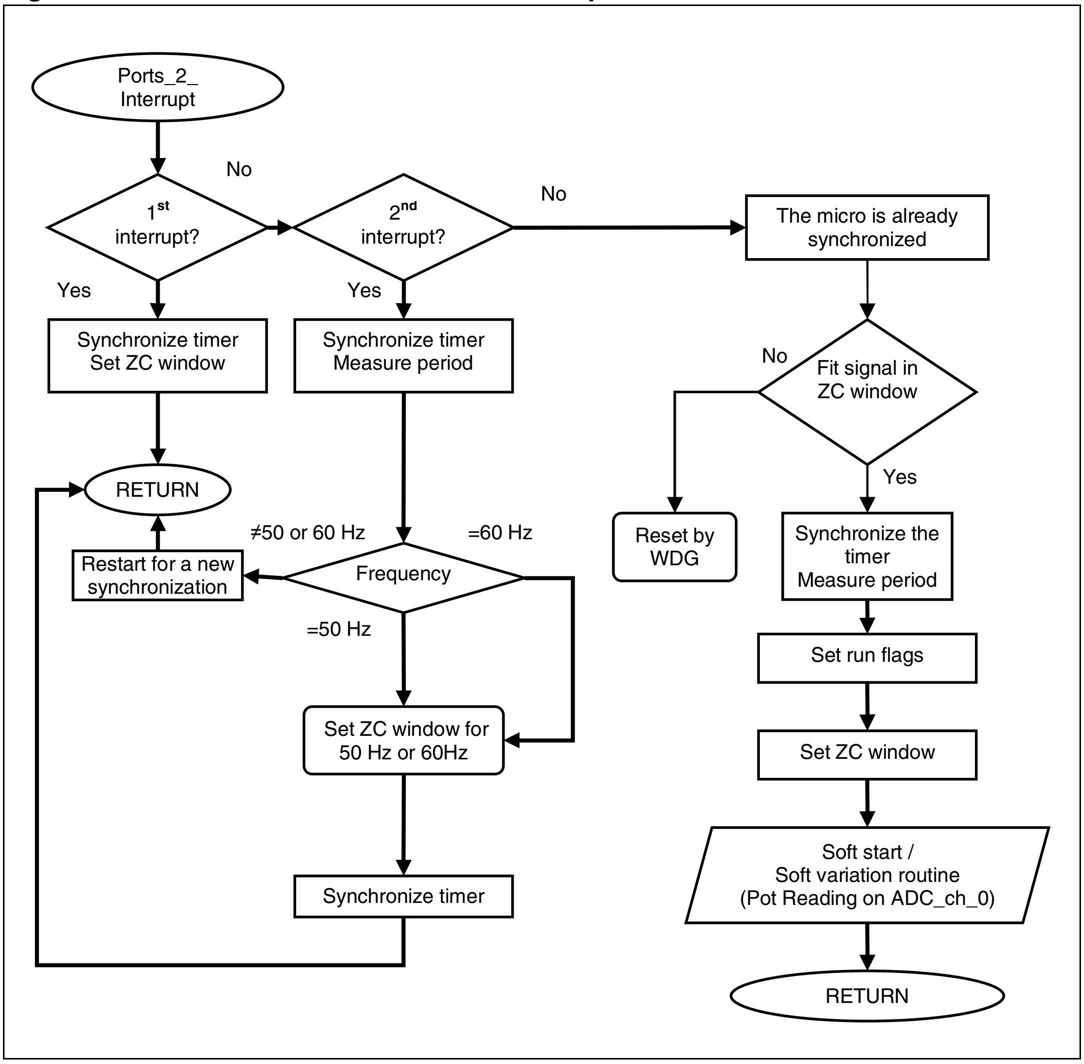
After the 50/60 Hz mains has been ON for a period of time (about 20 ms to 16.7 ms), the second ZC interrupt occurs. At this point the interval between ZC events is measured and based on this value. The corresponding flags are set (50 Hz or 60 Hz). If this event does not fit either the 50 Hz or 60 Hz parameters, all timer flags and the counter are re-initialized for another synchronization attempt.

The ZC window interval is ±1.2 ms. At the end of this interval, a new ZC event is set up. After a successful synchronization phase, the next ZC event is monitored during the following ZC interrupt and checked to see if the ZC interval passes synchronization parameters, or if the timer needs to be synchronized again. At this point, the fire angle (set through the potentiometer) will be read and updated according to the soft start / soft variation block.

This routine reads the potentiometer (ADC_ch0) and calculates the related value of phase angle. The actual phase angle will be incremented or decremented to reach the new value of the phase angle. All these tasks are done every 3 cycles of the MAINS (SOFT_VAR_COUNTER parameter) so we implement a soft variation of the motor rate avoiding an unexpected overcurrent event.

If the ZC interval is missed, the landmark counter is not updated and a watchdog reset occurs.

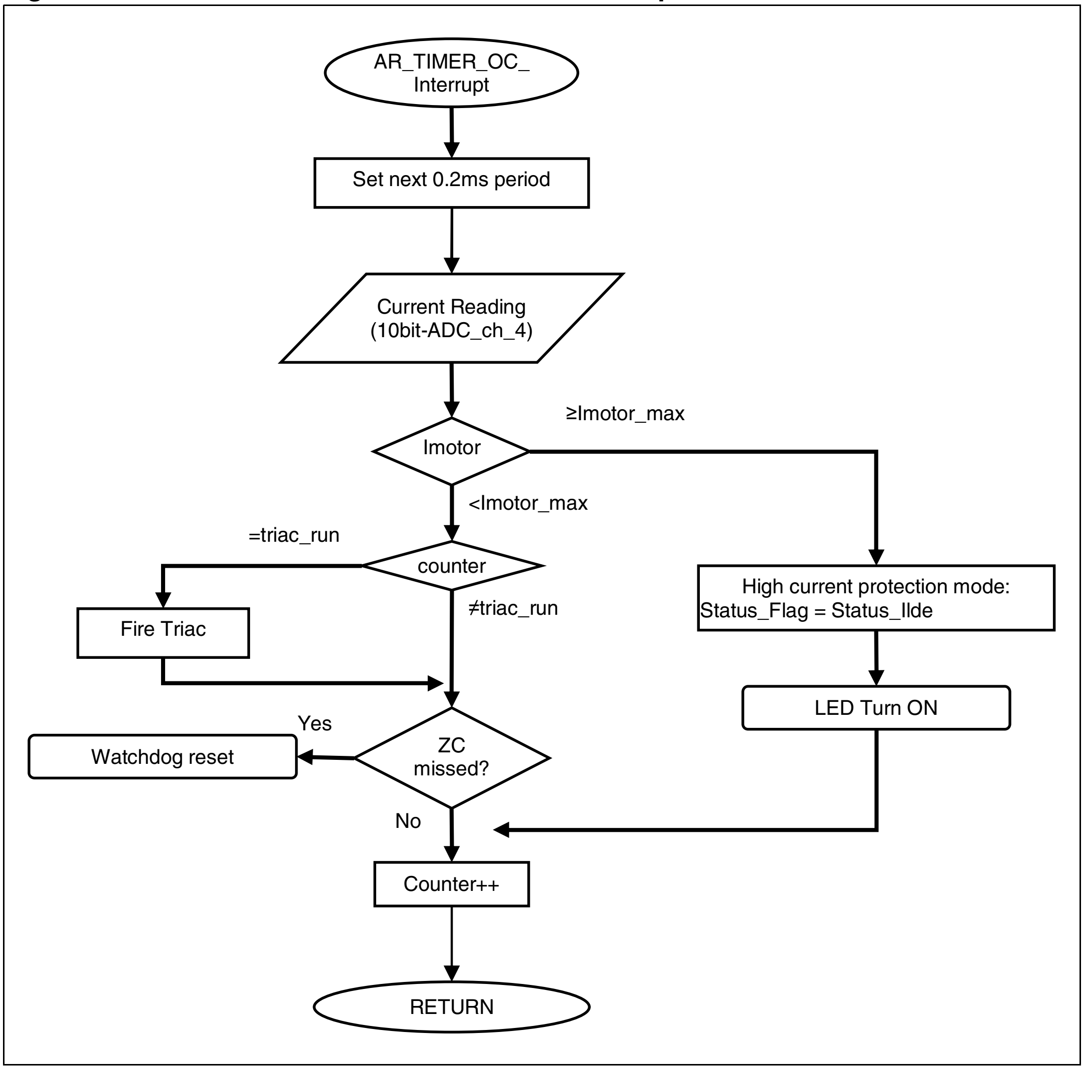
Figure 9. Flowchart of the PORTS_2_Interrupt routine



5.3 pwm_ar_timer_12bit.c

The AT timer in OC mode is used as the main time counter. This interrupt is handled in the AR_TIMER_OC_Interrupt routine. The AT timer is set to generate the 0.2 ms time base, start/stop push-button handling, TRIAC firing, and software counter incrementing (see *Figure 10*. The current reading occurs every 0.2 ms after the turn-on of the TRIAC through the 10bit-ADC analog input (channel 4). If the motor current value is higher than threshold (I_{MAX}), the main program goes in idle state (motor stops) and the LED is turned ON.

Figure 10. Flowchart of the AR_TIMER_OC_Interrupt routine



6 Experimental tests

The evaluation board has been configured and tested for a 1400 W motor (230 V/50 HZ).

The following plots have been made:

- The ZC signal (waveform 1)
- the motor current signal (waveform 2)
- the TRIAC driving signal before the transistor (waveform 3)

Examples of these plots are provided showing how the firing angle routine operates.

Two cases are given in *Figure 11* and *Figure 12*, one at maximum firing angle (minimum power) and another at minimum firing angle. When the high current protection routine works, the controller stops the motor, see *Figure 13*.

Figure 11. Waveforms: minimum power controlled

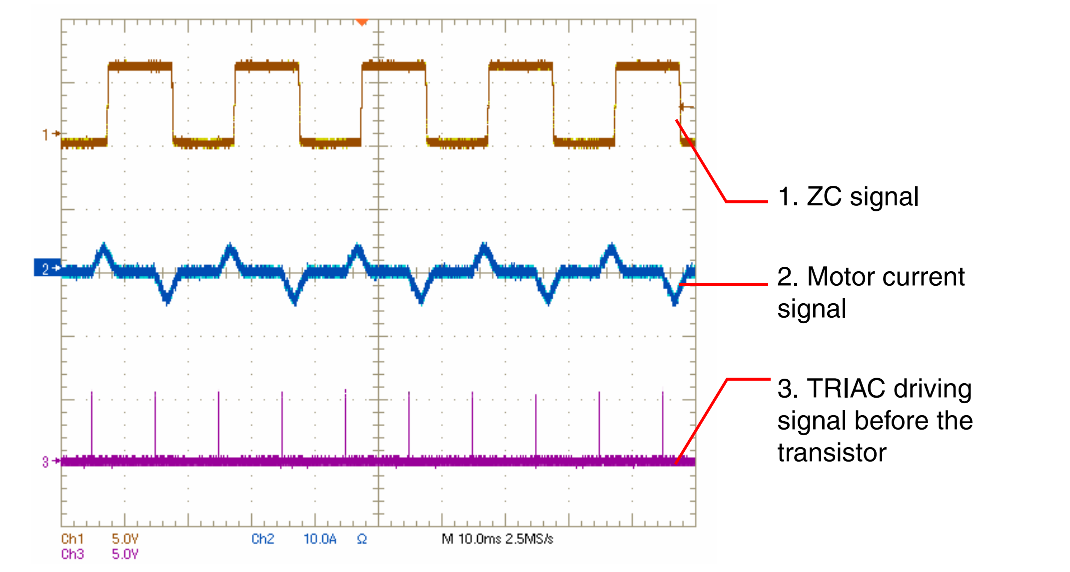


Figure 12. Waveforms: maximum power controlled

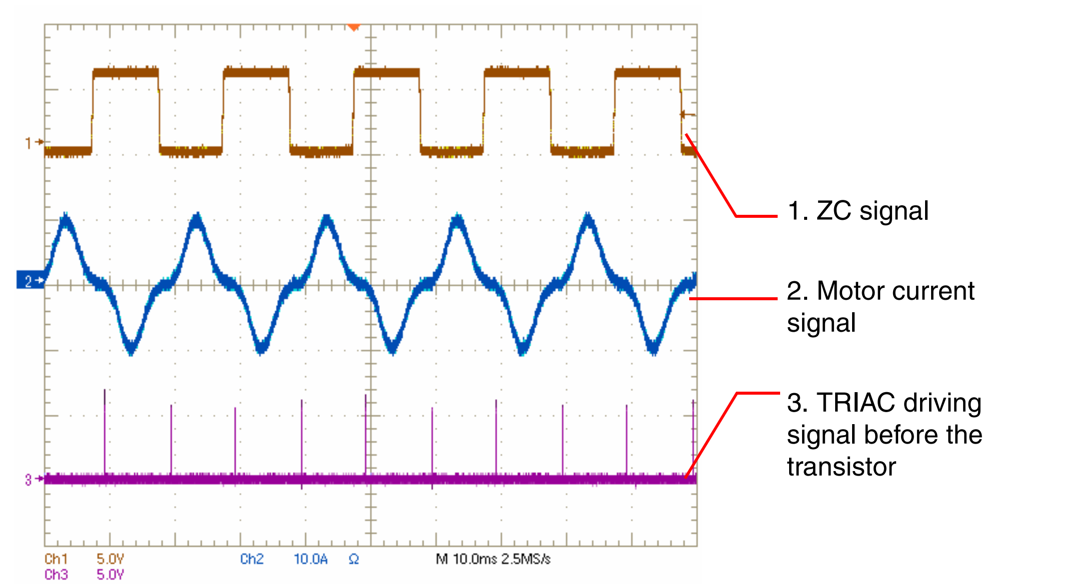
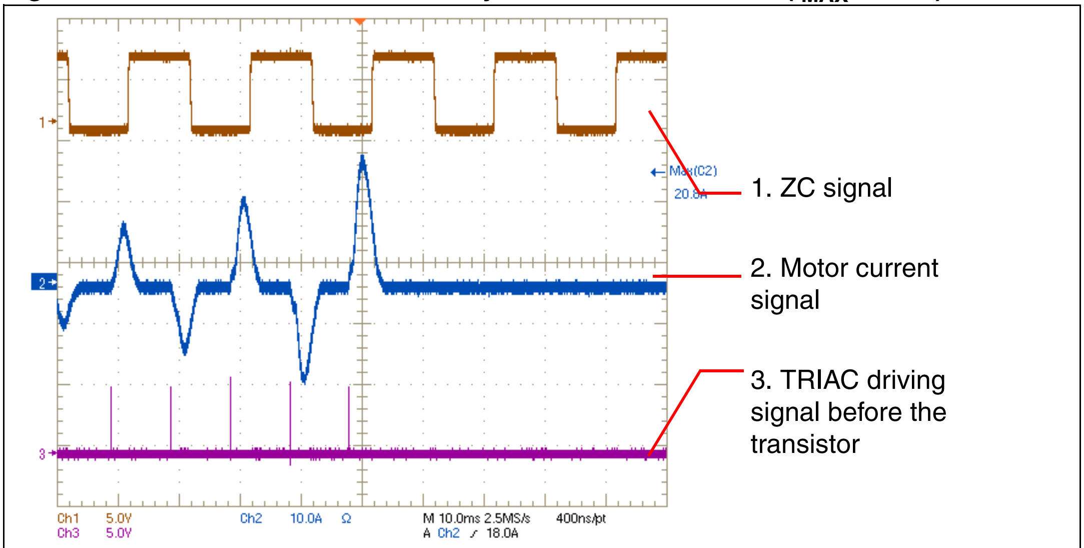
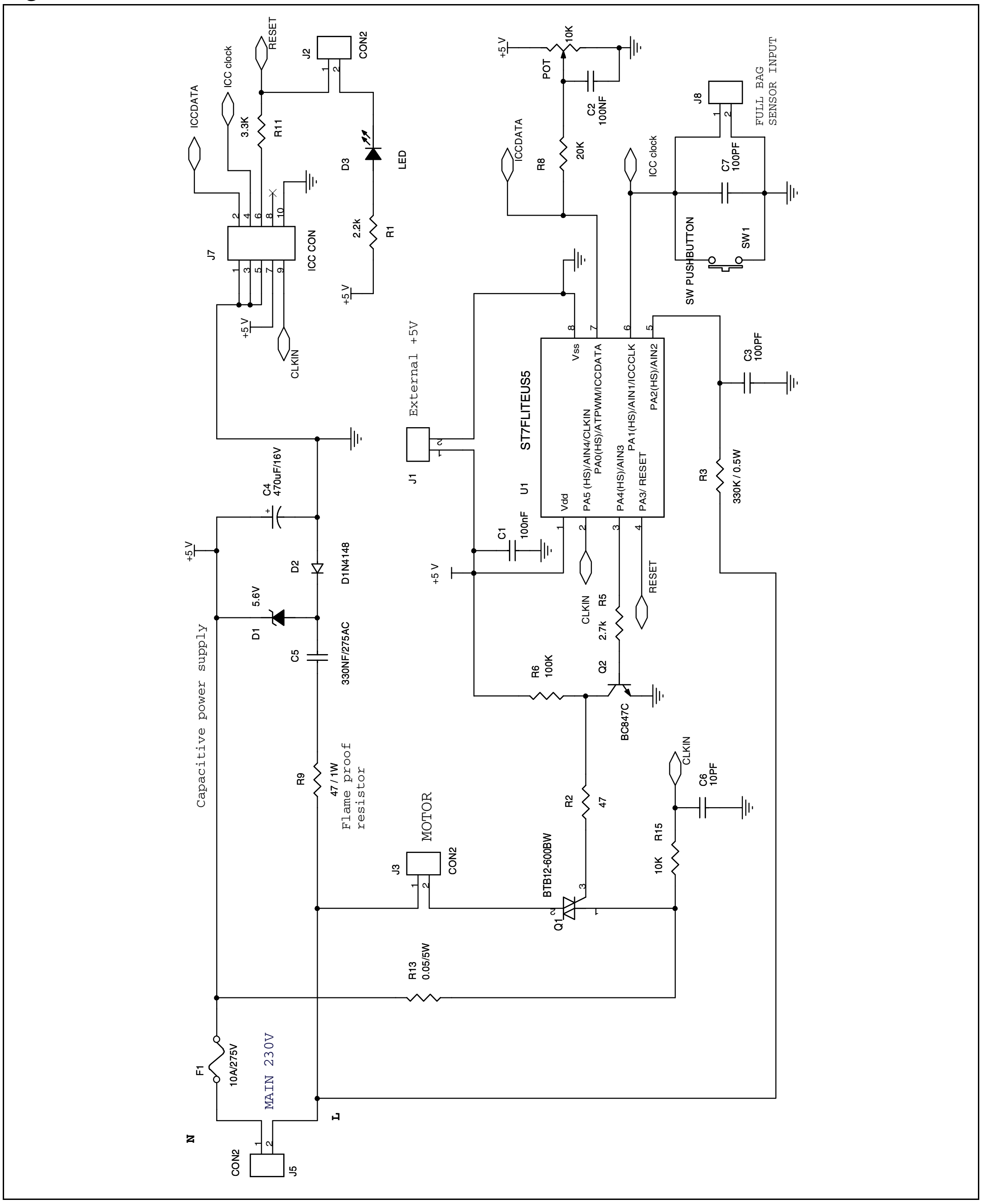


Figure 13. Waveforms: how the safety current routine works (I_{MAX} = 20 A)



7 Schematic

Figure 14. STEVAL-IHM0132V1 evaluation board schematic



8 Bill of material (BOM)

Table 4. Bill of material

Index	Quantity	Reference	Value / generic part number	Package	Manufacturer	Manufacturer's ordering code / orderable part number	Supplier	Supplier's ordering code
1	2	C1, C2	100 nF - 5%	SMD 0805				
2	2	C3, C7	100 pF - 5%	SMD 0805				
3	1	C4	470 µF / 16 V	electrolytic capacitor				
4	1	C5	330 nF/300V_{ac} 10%	AC capacitor X2			RS comp.	4419650
5	1	C6	1 nF - 5%	SMD 0805				
6	1	D1	5.6 V / 0.5 W	SMD 1206				
7	1	D2	D1N4148	SMD 1206				
8	1	D3	Red LED	SMD 1206				
9	1	F1	10 A / 275 V	FUSE				
10	3	J1,J2, J8	CON2	2 pin strip line 2.54 mm				
11	2	J3, J5	Terminal blocks	7.62 mm pitch - 2 wires	Phoenix contact	1731721	RS comp.	1895966
12	1	J7	ICC CON	10 pin strip dual in line 2.54 mm				
13	1	POT	10 kΩ				RS comp.	855383
14	1	Q1	BTB12-600BW	TO220AB	ST	BTB12-600BWRG		
15	1	Q2	BC847C	SOT23				
16	1	R1	2.2 kΩ - 1%	SMD 0805				
17	1	R2	47 - 1%	SMD 0805				
18	1	R3	330 kΩ - 1% / 0.6 W	Metal film resistor			RS comp.	506-5591
19	2	R5	2.7 kΩ - 1%	SMD 0805				
20	1	R6	100 kΩ - 1%	SMD 0805				
21	1	R8	20 kΩ - 1%	SMD 0805				
22	3	R9	47 / 1 W - 5%	Flame proof resistor			RS comp.	2140964

Table 4. Bill of material (continued)

Index	Quantity	Reference	Value / generic part number	Package	Manufacturer	Manufacturer's ordering code / orderable part number	Supplier	Supplier's ordering code
23	1	R11	3.3 kΩ - 1%	SMD 0805				
24	1	R13	0.05 / 5 W				Distrelec	710522 LOB5
25	1	R15	10 kΩ	SMD0805				
26	1	SW1	BUTTON				E-Switch	TL1100EF160Q
27	1	U1	ST7FLITEUS5	SO-8	ST	ST7FLITEUS5M6		
28	1		Heatsink	Base: 25x15 mm h: >20 mm			ELCART	Code: 4/9610
29	1		Jump	On J2			ELCART	Code: 5/7649

9 References and related materials

Additional information can be found from the ST website: *http://www.st.com/*

Datasheets:

- ST7FLITEUS5 datasheet
- BTB12 datasheet

Application notes:

- AN2263 - Universal motor speed control and light dimmer with TRIAC and ST7LITE microcontroller
- AN439: Improvement in the TRIAC commutation
- AN437: New TRIACs: is the snubber circuit necessary?
- AN533: SCRs, TRIACs and AC switches: thermal management precautions for handling and mounting
- AN1476: Low-cost power supply for home appliances.
- AN1015: Software techniques for improving microcontroller EMC performance.

Appendix A Capacitor value according to country

Table 4 indicates the capacitor value for a 8 mA average current in standard condition (nominal capacitor value, nominal RMS line voltage) versus different AC mains and frequency values used in different countries.

Table 5. C5 capacitor value according to country

Country	Typical RMS Voltage	Minimum RMS voltage	Frequency	C5 capacitor	Max. output average current for standard conditions	Max. output average current for worst case
Japan	100 V	90 V	50/60 Hz	1 µF	16.3 mA	10.8 mA
USA	120 V	100	60 Hz	680 nF	13.4 mA	9.8 mA
Brazil, Mexico	120 V to 240 V	102 V to 204 V	50/60 Hz	680 nF	22.7 mA	10.1 mA
Europe, China, Korea, Australia	220 V to 240 V	187 V to 204 V	50/60 Hz	330 nF	11 mA	7.6 mA

10 Revision history

Table 6. Document revision history

Date	Revision	Changes
21-Nov-2007	1	Initial release