AN2716

STCC08 application guidelines

Introduction

The purpose of this document is to:

- Describe the STCC08 device features
- Give technical recommendations to:
  - Implement the STCC08 in the appliance
  - Achieve robust STCC08 design regarding EMI tests (IEC 61000-4-4)

Contents

1 STCC08 description

1.1 Main features

The STCC08 was designed to improve the safety of home appliances (see Reference 1.). This new device can drive up to 10 mA I_{GT} AC switches (TRIAC, ACST and ACS - see Reference 2.) and send back to the microcontroller (MCU) a signal image of the voltage across the controlled AC switch. The STCC08 has three functional blocks (see *Figure 1* and *Table 1*).

- A “gate driver” block used to drive an AC switch and to interface directly the STCC08 with the MCU (CMOS compatible)
- A “power switch signal shaping” block used to measure the AC switch voltage
- An “AVF driver” block used to give an image of the AC switch voltage to the MCU (digital information)

Figure 1. STCC08 block diagram

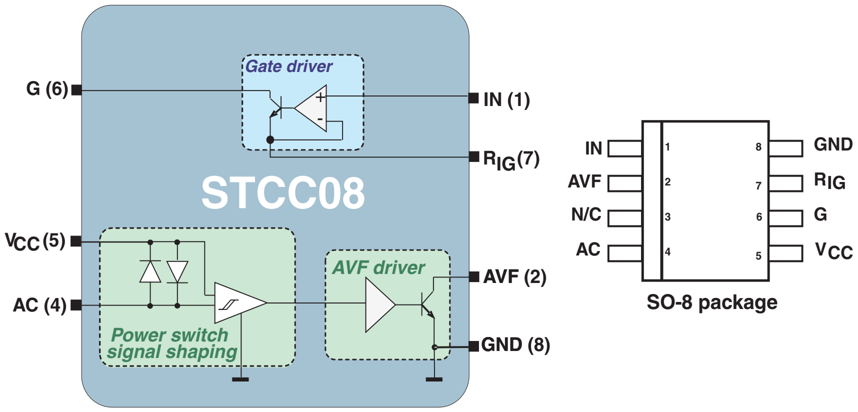


Table 1. STCC08 pin descriptions

Pin	Symbol	Type	Description
1	IN	SIGNAL	AC switch drive
2	AVF	SIGNAL	Alternating voltage feedback: AC switch state output
3	NC		Not connected
4	AC	SIGNAL	AC switch state sense input
5	V_{CC}	POWER	Positive power supply
6	G	SIGNAL	AC switch gate driver output
7	R_{IG}	SIGNAL	AC switch gate current setting
8	GND	POWER	Power supply reference

Knowing the STCC08 IN input state (used to turn on or off the AC switch) and the voltage across the controlled AC switch (given by the STCC08 AVF output signal state), the MCU is able to identify all AC switch failures (diode mode, short circuit, or open circuit) and to take the appropriate actions to put the appliance in a secure state (see Reference 3.) by switching off an appliance front-end relay (see *Section 1.4.3*).

1.2 STCC08 non-insulated and insulated application diagram

The STCC08 is dedicated to applications with MCU. *Figure 2* and *Figure 3* show respectively the STCC08 non-insolated and insolated application diagrams. The STCC08 is compatible with 3.3 V and 5 V power supplies. The DC power supply must be a negative one. This means the V_{cc} terminal has to be connected to neutral. The GND voltage is then V_{CC} (3.3 V or 5 V) below neutral. Such a connection is mandatory to drive ACS and most ACST and TRIAC devices (AC switches can be triggered only by a current taken from the gate).

Figure 2. Un-insulated application diagram

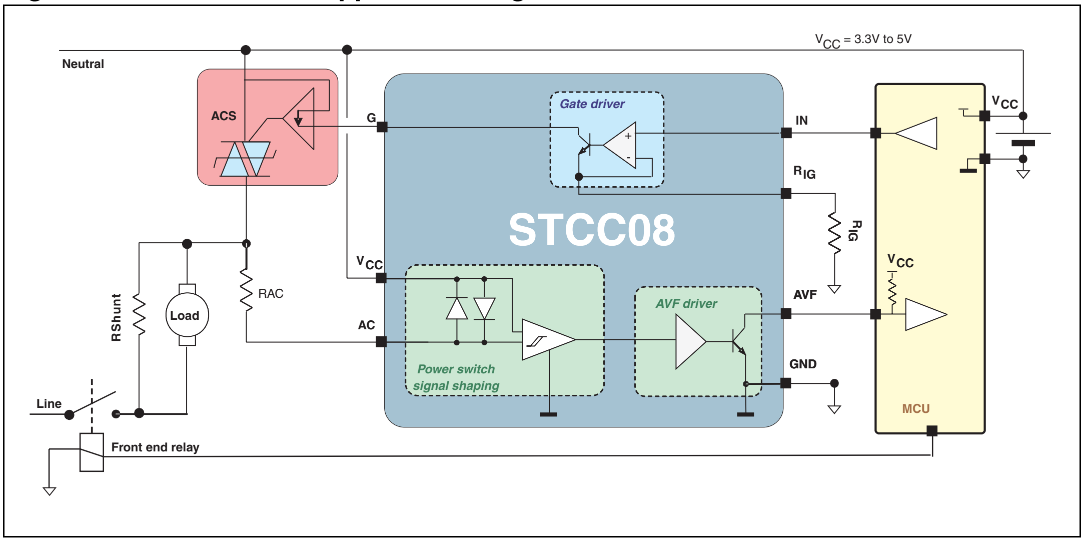
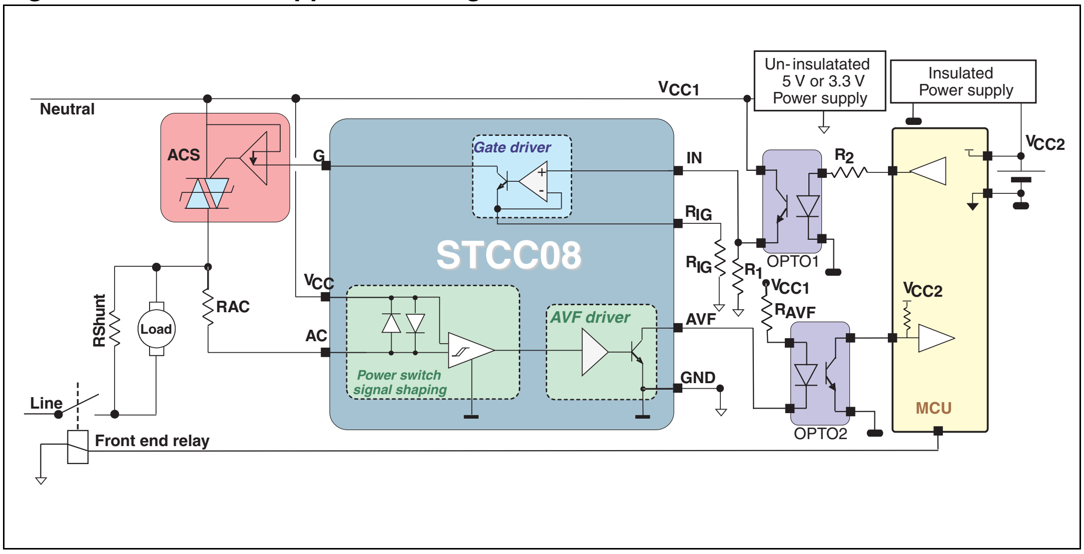


Figure 3. Insulated application diagram



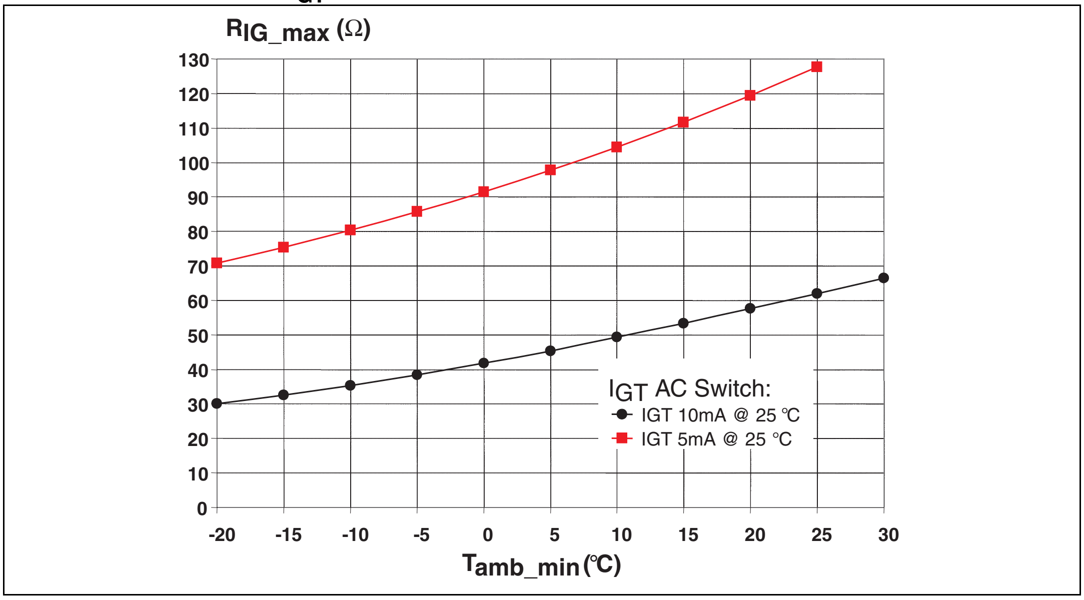
1.3 AC switch control

The STCC08 controls up to 10 mA I_{GT}TRIAC, ACST and ACS through the "gate driver" block designed to:

- Drive the AC switch according to the IN control input state (CMOS compatible)
  - For IN = 1 = V_{CC} ⇨ the AC switch is turned on
  - For IN = 0 = GND ⇨ the AC switch is turned off
- Regulate the gate current of the AC switch thanks to the internal current controller

The gate current value (Pin G - to turn on the AC switch) is defined by the external resistor R_{IG} value (resistor connected between the STCC08 R_{IG} input and ground). *Figure 4* gives the maximum value of this resistor (R_{IG_max}) according to the minimum ambient temperature (T_{amb_min}) of the appliance for two AC switch I_{GT} values. Note that as the AC switch junction temperature increases when the AC switch is on ($T_j > T_{amb}$), the I_G gate current required to turn on the AC switch decreases ($I_G < I_{GT}$). So only the minimum ambient temperature has to be considered.

Figure 4. Resistor R_{IG} value according to the minimum ambient temperature and AC switch I_{GT}



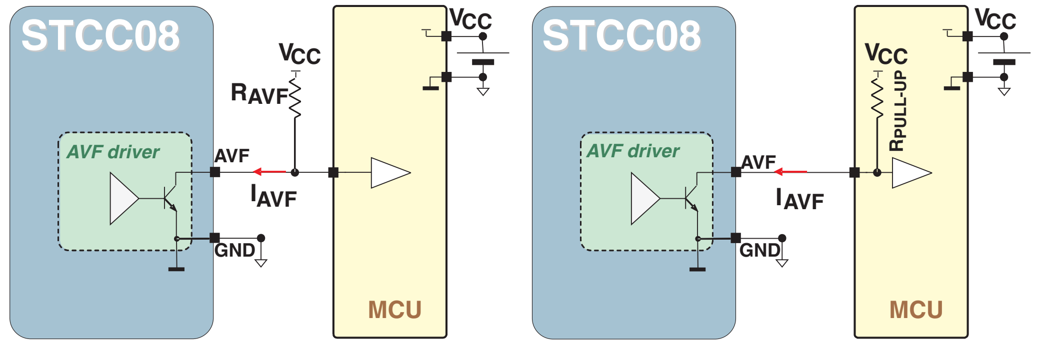
For example, with a 10 mA I_{GT} AC switch and a -20 °C minimum ambient temperature, a maximum 30 Ω R_{IG} resistor can be used to turn on the AC switch throughout the whole appliance temperature range.

1.4 AC switch failure mode detection

1.4.1 STCC08 AVF output configuration

The STCC08 AVF driver block is used to send the AC switch state to the MCU (see *Section 1.4.2*). The STCC08 AVF output is an open collector and can be loaded with an external resistor (R_{AVF}) or connected directly to the MCU, in pull-up input configuration (see *Figure 5*).

Figure 5. STCC08 AVF output configuration



(a) AVF output loaded with an external resistor (R_{AVF}) (b) AVF output loaded with the MCU pull-up resistor ($R_{PULL-UP}$)

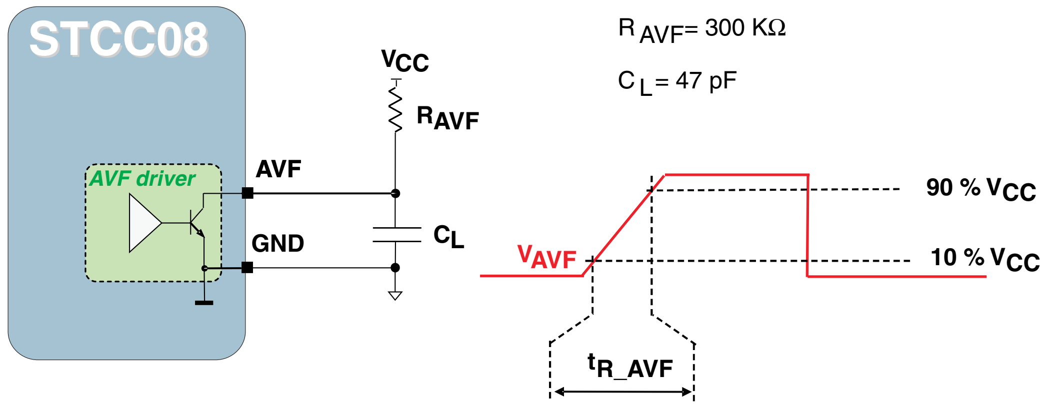
The I_{AVF} current in the STCC08 AVF pin must be lower than 5 mA (I_{AVF_max}). *Equation 1* defines the minimal R_{AVF} or pull-up resistor value to use. For example, with V_{CC_max} = 5.5 V, the R_{AVF} or $R_{PULL-UP}$ resistor value must be higher than 1.1 kΩ to fulfill this condition.

Equation 1

$$R_{AVF\_min} \text{ or } R_{PULL\text{-}UP\_min} > \frac{V_{CC\_max}}{I_{AVF\_max}(5\ mA)}$$

The AVF signal toggles from V_{CC} to GND according to the AC switch state and the AC line (see *Section 1.4.2*). The R_{AVF} or $R_{PULL-UP}$ resistor values modify the AVF signal rise time (t_{R_AVF}). This rise time increases with the MCU I/O pin capacitance and R_{AVF} or $R_{PULL-UP}$ resistors. To limit the influence of this delay on the AC switch state detection (see *Section 1.4.2*) and on the ZVS detection application (see *Section 4*), a 300 kΩ maximum R_{AVF} or $R_{PULL-UP}$ resistor value is recommended. With a 47 pF C_L load capacitor and a 300 kΩ maximum R_{AVF} resistor, the AVF rise time is typically about 50 µs (see *Figure 6*).

Figure 6. AVF signal rising time measurement information



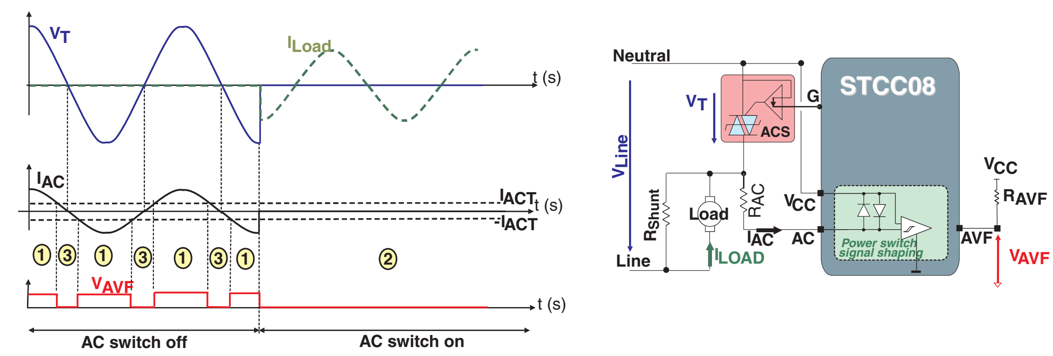
1.4.2 AC switch state detection principle

The AC switch state detection is achieved thanks to the STCC08 “power switch signal shaping” block. This block measures the current (I_{AC}) through the STCC08 AC input, which is the image of the AC switch voltage (V_T) during both AC line cycle (V_{Line}). As illustrated in *Figure 7*, three cases can be considered.

- Case 1: If the AC switch is off ($V_T = V_{Line}$), a low I_{AC} current, in phase shift with the AC line (see *Section 1.5.1*), flows through resistor R_{AC} for the both AC line polarities. In this case, the STCC08 AVF output signal (V_{AVF}) remains at high level state ($+V_{CC}$).
- Case 2: If the AC switch is on ($V_T \approx 0$), no I_{AC} current flows through the resistor R_{AC}. In this case, the AVF output signal (V_{AVF}) remains at low level state (GND).
- Case 3: If the AC switch is off and the AC line voltage falls to zero voltage, no I_{AC} current flows through the resistor R_{AC}. In this case, the AVF output signal (V_{AVF}) goes to zero level (GND).

Knowing the STCC08 IN input state, the MCU is then able to determine the AC switch state by analyzing the AVF signal (see *Section 1.4.3*).

Figure 7. AC switch failure detection principle



The I_{AC} current follows the waveform of the voltage across the AC switch. The AVF signal toggles between V_{CC} and zero level (GND) at a certain I_{AC} current value noted as I_{ACT} (see *Figure 7*). The I_{ACT} electrical parameter dispersion is shown in *Table 2.*

Table 2. I_{ACT} electrical parameter dispersion

	Maximum (I_{ACT_max})	Minimum (I_{ACT_min})
I_{ACT}	236 µA	82 µA

The I_{AC} peak current value ($I_{AC\text{-}peak}$) must be lower than 2.2 mA (maximum I_{AC} current allowed through STCC08 AC input). *Equation 2* defines the minimum resistor R_{AC} value (R_{AC_Min}) to limit this I_{AC} current in the worst case (if the AC load fails in short circuit). For example, with $V_{Line\_rms\_max}$ = 230 V + 10%, the R_{AC} resistor value must be higher than 163 kΩ.

Equation 2

$$R_{AC\_min} > \frac{\sqrt{2} \times V_{Line\_rms\_max}}{I_{AC\_peak\_max}\ (2.2\ \text{mA})}$$

The resistor R_{Shunt} is used to detect the AC switch state whatever the AC load state is (connected or disconnected). Without this resistor, the STCC08 AVF signal remains at low level (GND) whatever the AC switch state when the AC load is disconnected ($I_{AC} = 0$). To detect the AC switch state when the AC load is disconnected (with the resistor R_{Shunt}), the $I_{AC\text{-}peak}$ current remains higher than the I_{ACT_Max} current (I_{AC} current threshold to ensure the AC switch state detection - see *Table 2*). *Equation 3* defines the condition on R_{AC} and R_{Shunt} resistors to ensure a right AC switch states detection in the worst case (if the AC load is disconnected). For example, with $V_{Line\_RMS\_Min}$ = 230 V - 10%, the R_{AC} resistor value plus the R_{Shunt} resistor value must be lower than 1.24 MΩ.

Equation 3

$$R_{Shunt\_max} + R_{AC\_max} < \frac{\sqrt{2} \times V_{Line\_rms\_min}}{I_{ACT\_max}\ (236\ \mu A)}$$

To limit the power dissipation by resistors R_{AC} and R_{Shunt} lower than ¼ W and their influences on the AC load, a 300 kΩ and 100 kΩ minimum value is recommended respectively under 230 V rms and 100 V rms AC line. *Equation 4* and *Equation 5* give the power dissipation for R_{AC} and R_{Shunt} in the worst case.

Equation 4

$$(P_{RAC})_{max} = \frac{(V_{Line\_rms\_max})^2}{R_{AC\_min}}$$

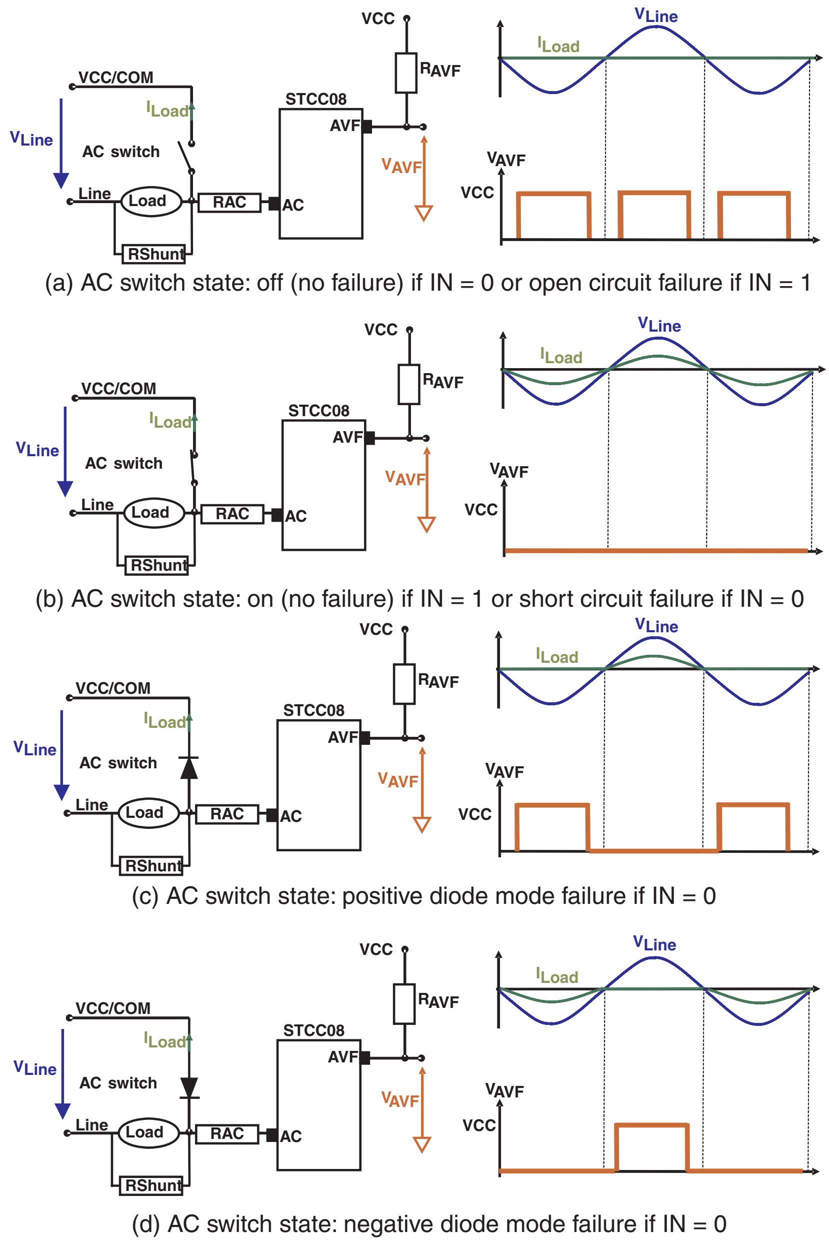
Equation 5

$$(P_{RShunt})_{max} = \frac{(V_{Line\_rms\_max})^2}{R_{Shunt\_min}}$$

1.4.3 AC switch failures detection during normal operation

Knowing the STCC08 IN input state, the MCU is able to determine the AC switch state by analyzing the AVF signal. *Figure 8* and *Table 3* give the AC switch failure modes according to the AVF signal state and the STCC08 IN signal state. In case of AC switch failure, the MCU can put the appliance in a safe configuration by switching off an appliance front-end relay.

Figure 8. AC switch failure detection



(a) AC switch state: off (no failure) if IN = 0 or open circuit failure if IN = 1

(b) AC switch state: on (no failure) if IN = 1 or short circuit failure if IN = 0

(c) AC switch state: positive diode mode failure if IN = 0

(d) AC switch state: negative diode mode failure if IN = 0

Table 3. STCC08 status truth table

MCU control (IN)	AVF output state [1]	AC switch state
0	$+V_{CC}$ (Except at each zero crossing of the AC line)	Off (no failure)
0	Toggle from $+V_{CC}$ to 0	Diode mode
0	0	Short-circuit
1	0	On (no failure)
1	$+V_{CC}$ (Except at each zero crossing of the AC line)	Open-circuit

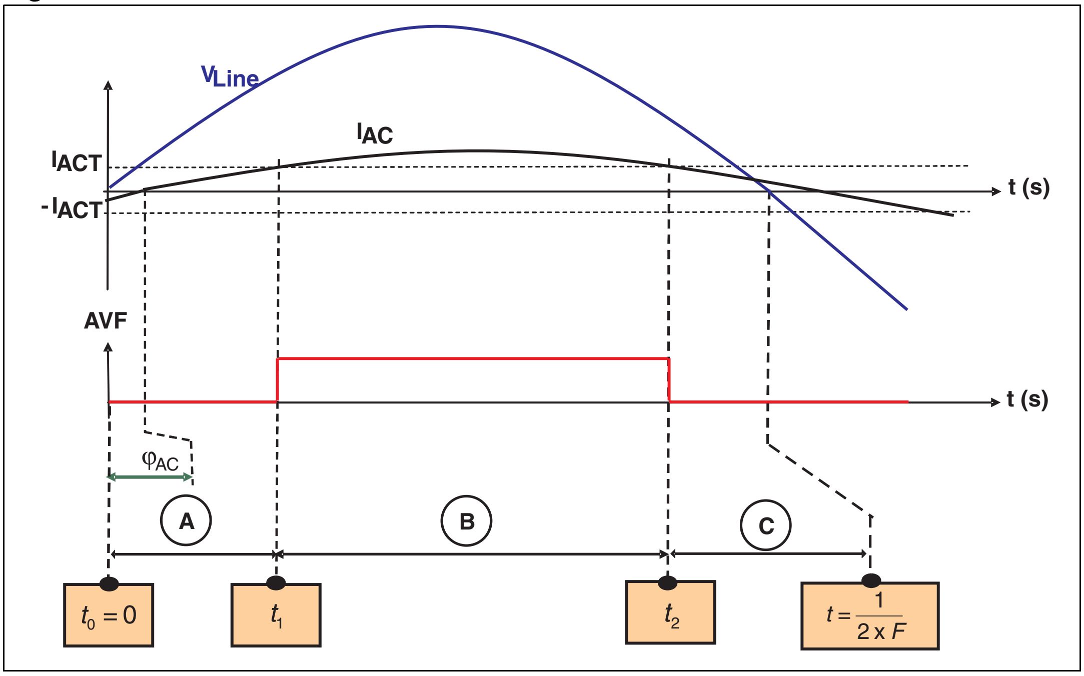
1. The AVF output must be loaded with an external resistor (R_{AVF}) or connected directly to the MCU, in pull up input configuration (see *Section 1.4.1*).

1.5 AVF signal reading synchronization

1.5.1 Detection window width definition

When the AC switch is off (not controlled or failed in open circuit), an I_{AC} current flows through the STCC08 AC input. The value of this current depends on R_{AC} and R_{shunt} resistors, the AC line voltage, and the AC load impedance. The AVF signal toggles between V_{CC} and zero level (GND) for an I_{AC} current value noted I_{ACT} (see *Figure 9*). This has an impact on the AC switch state detection. If the STCC08 is not controlled (IN = 0) and the AVF signal is read when the I_{AC} current is lower than I_{ACT}, the AC switch can be interpreted as failed in short circuit (see *Table 3*).

Figure 9. STCC08 AVF version when the AC switch is off

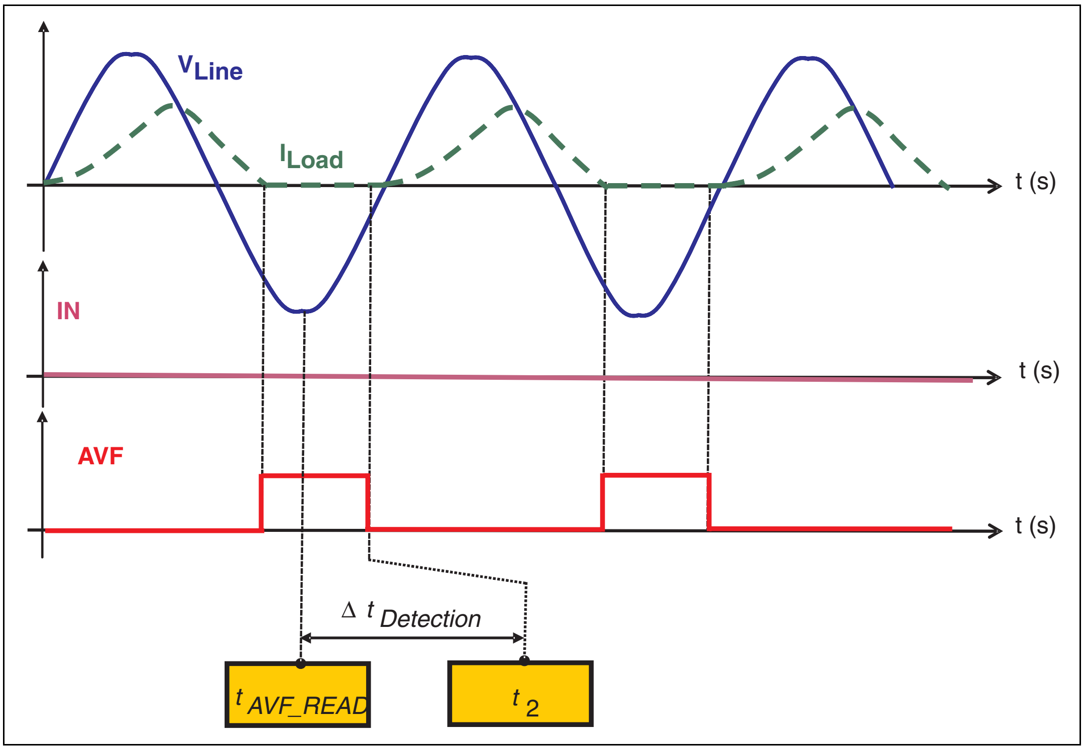


Note: *ϕ_{AC} is the phase shift between the AC line and the I_{AC} current when the AC switch is off. This phase shift is very low and can be neglected for most AC loads found in home appliances (see Appendix A).*

The t_1 and t_2 values are defined in *Appendix A*. For example, with $R_{AC} = R_{Shunt} = 300\ k\Omega$, $F = 50$ Hz, $V_{AC\_Line} = 230$ V, a minimum rms current and a phase shift of the AC load respectively equal to 0.1 A and 90°, t_1 and t_2 are respectively 1.7 ms and 8.3ms.

When the AC switch is failed in diode mode, the AC switch is on during only half of the AC line cycle for resistive load (the load current is in phase with the AC line voltage). In this case, the AVF signal falls to GND at each cycle of the AC line when the AC switch is on. However, with an inductive load, the load current (I_{Load}) falls to zero after the zero crossing of the AC line voltage (See *Figure 10*). This has an impact on the AC switch state detection. If the AC switch has failed in diode mode and the STCC08 AVF signal is read just after each zero crossing of the AC line voltage, the AC switch failed in diode mode will not be discriminated from the AC switch short circuit failure.

Figure 10. Load current and STCC08 AVF variation when the AC switch is failed in diode mode



The STCC08 AVF signal should be read after the AC line peak voltage (t_{AVF_READ}) (See *Equation 6*) and before the time t_2 to detect all AC switch states for most home appliance loads.

Equation 6

$$t_{AVF\_READ} > \frac{1}{4 \cdot F_{Min}}$$

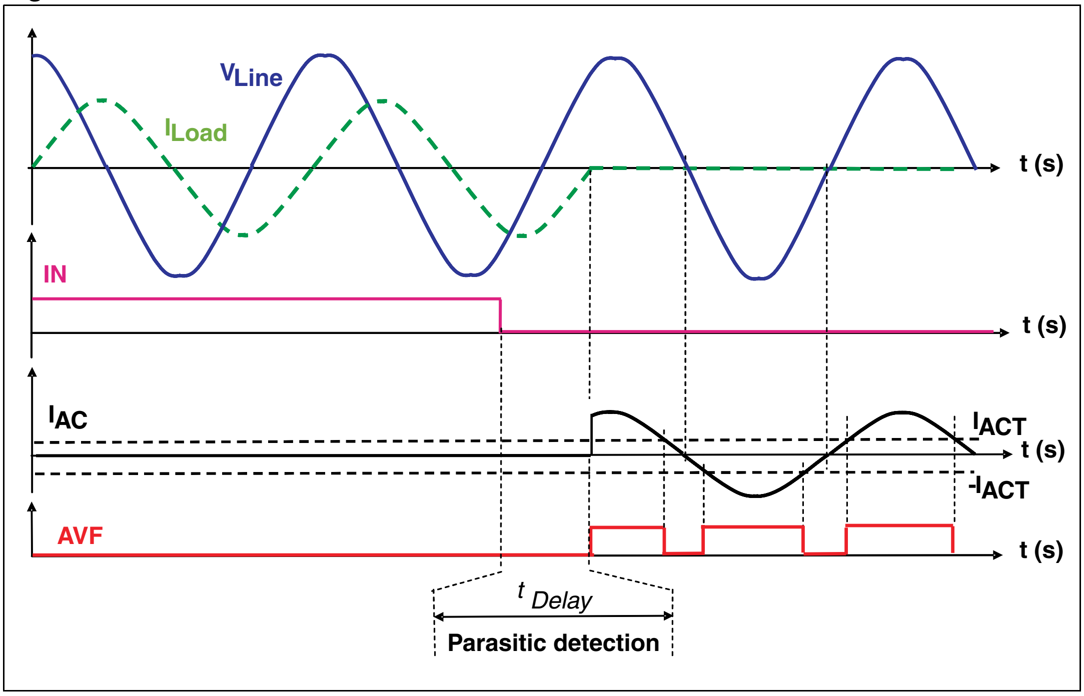
Note: *Note, if the STCC08 AVF signal is read between times t_1 and t_2 (see Figure 9), all the AC switch failures will be detected but the AC switch failed in diode mode will be confused with the AC switch failed in short-circuit.*

To detect the AC switch state when the STCC08 is controlled by a pulsed gate current, the MCU should store the IN signal state in a RAM register. This RAM register could be initialized at each zero crossing of the AC line voltage.

1.5.2 AC switch state detection after IN signal removal

When the IN signal is removed (to turn on or off the AC switch), a parasitic detection of the AC switch state exists up to the next AC load current zero (see *Figure 11* for AC inductive load case). As the AVF signal remains at a low-level state when the control is removed ($I_{LOAD} \neq 0$), the AC switch can be interpreted as an AC switch short circuit failure.

Figure 11. Parasitic detection for inductive load



To ensure a correct detection of the AC switch state and to take into account the AC switch failed in diode mode, when the IN control is removed and whatever the AC load used, the AVF reading must be carried out according to *Equation 7*. For example, with F = 50 Hz, the AVF signal can be read after 20 ms when the IN control has been removed.

Equation 7

$$t_{Delay\_min} > \frac{1}{F}$$

Note: *Overall, the AVF signal should be read during several AC line cycles to avoid an incorrect interpretation of the AC switch state.*

2 STCC08 consumption

Equation 8, *Figure 12*, and *Table 4* define the maximum STCC08 current consumption (I_{DC_max}). The current I_{AC} is used only to detect the AC switch states. This current comes from the AC line and not from the STCC08 DC power supply. The current I_G is the gate current to turn on the AC switch, defined according to the external resistor R_{IG} value (see *Figure 13*). The current $I_{Quiescent}$ defines the STCC08 quiescent current. The maximum $I_{Quiescent}$ current is specified at 2 mA. The maximum IN input current (I_{IN_Max}) is specified at 100 µA. The AVF current, used to polarize the STCC08 AVF output is defined by the resistor R_{AVF} or by the MCU pull up resistor (see *Equation 9*).

Equation 8

$$I_{DC\_max} = I_{G\_max} + I_{AVF\_max} + I_{Quiesient\_max} + I_{IN\_max}$$

Figure 12. STCC08 current consumption

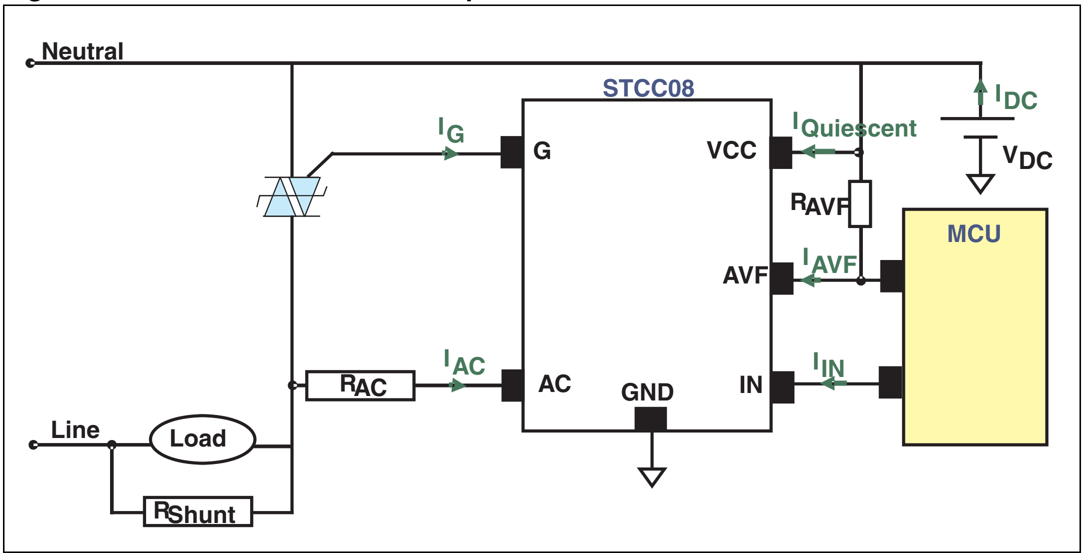


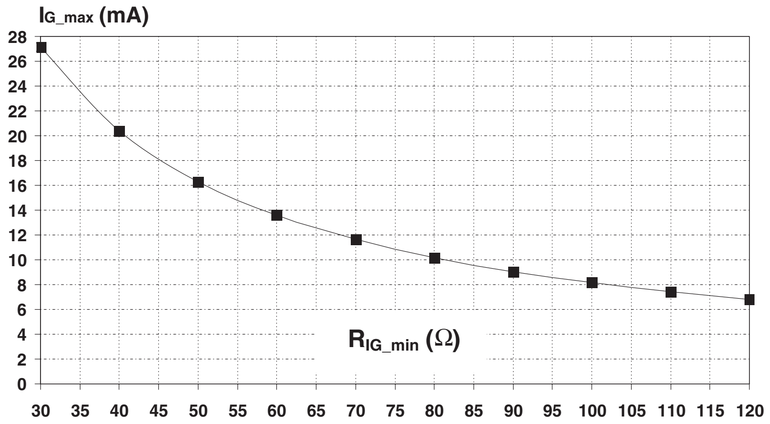
Table 4. STCC08 consumption values

Parameter	Definition	Maximum value
I_{G_max}	AC switch gate current	Depends on the R_{IG} resistor. See *Figure 13*
$I_{Quiescent}$	STCC08 current consumption	2 mA
I_{AVF}	AVF pin collector current	Depends on the R_{AVF} resistor (I_{AVF_max} = 5 mA). See *Equation 9*
I_{IN}	IN input current (to control the AC switch)	100 µA

Equation 9

$$I_{AVF\_max} = \frac{V_{CC\_max}}{R_{AVF\_min}} = \frac{V_{CC\_max}}{R_{Pull\text{-}up\_min}}$$

Figure 13. Maximum I_G current (I_{G_max}) versus resistor R_{IG} value



For example, with R_{IG} = 30 Ω, V_{CC_max} = 5.5 V and R_{AVF} = 10 kΩ, the maximum STCC08 current consumption is about 30 mA.

3 Recommended component values

Figure 14 and *Table 5* show the application diagram and the recommended values to implement the STCC08 device in the appliance according the AC line voltage.

Figure 14. Application diagram

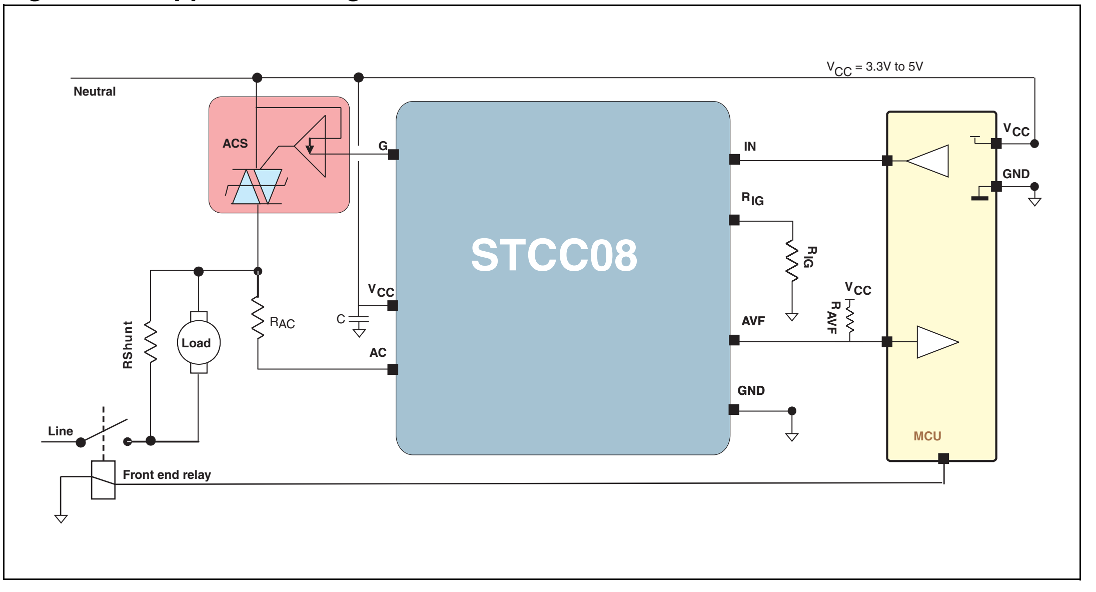


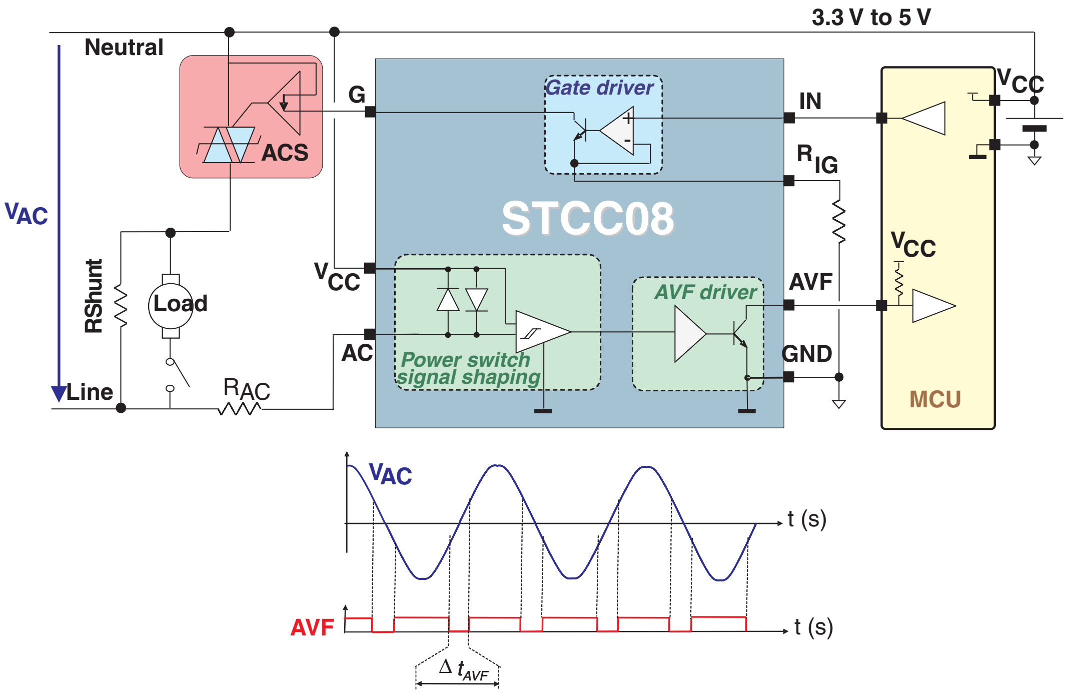
Table 5. Recommended value

		V_{Line}	
		230 V rms at 50 Hz	**110 V rms at 50 Hz**
R_{Shunt}		300 kΩ @ ¼ W	100 kΩ @ ¼ W
R_{AC}		300 kΩ @ ¼ W	100 kΩ @ ¼ W
R_{AVF}		10 kΩ @ ¼ W	10 kΩ @ ¼ W
R_{IG}	I_{GT} = 10 mA @ -20 °C	30 Ω ± 1% @ ¼ W	30 Ω ± 1% @ ¼ W
	I_{GT} = 5 mA @ -20 °C	68 Ω ± 1% @ ¼ W	68 Ω ± 1% @ ¼ W
C		33 nF	33 nF
t_{AVF_READ}		5.1 ms	5.1 ms
t_{2_min} (see *Appendix A*)		8.3 ms	8.9 ms
$\Delta t_{Detection\_min}$		3.2 ms	3.8 ms

4 ZVS detection application

The STCC08 “Power switch signal shaping” block can be used to detect the zero crossing of the AC line voltage. The resistor R_{AC} must be connected between AC input and the AC line as shown in *Figure 15*. The AVF signal toggles between V_{CC} and zero level at each zero crossing of the AC line voltage.

Figure 15. ZVS detection



Equation 10 defines the maximal AVF signal low level width (Δt_{AVF}) at each zero crossing of the AC line voltage according to the value of resistor R_{AC}.

Equation 10

$$\Delta t_{AVF\_max} = \frac{1}{\cdot \pi \cdot F_{min}} \times \text{Arsin}\left(\frac{I_{ACT\_max} \cdot R_{AC\_max}}{\sqrt{2} \cdot V_{rms\_min}}\right)$$

5 Electromagnetic compatibility (EMC) tests

5.1 Demonstration board description

The STCC08 has been tested using a stand-alone demonstration board (see *Appendix B*) and according to IEC 61000-4-4. *Appendix C* and *Appendix D* give respectively the electrical schematic and the layout of the demonstration board. This demonstration board can work on 110 V / 230 V rms 50 / 60 Hz mains voltage. The STCC08 board includes:

- The STCC08
- The ACS108-6S
- An STLITE39 MCU.
- A capacitive power supply (C15 = 10 nF)
- An In-dart connector to load the MCU firmware
- Mechanical switches used to simulate different AC switch failures (diode mode, short circuit and open circuit)
- A mechanical switch to control the STCC08 IN signal through MCU
- LEDs used to visualize the detected ACS failure modes.
- An AC load: light bulb (15 W at 230 V rms)

The STLITE39 MCU is used to turn the ACS108-6S on / off through the STCC08 and to analyze the AVF signal to power LEDs indicating AC switch states and failures (AC switch ON, diode mode, short circuit and open circuit).

Regarding the power supply, the maximum average current absorbed by the board is about 48 mA. A 2.2 µF C16 capacitor has been used to ensure the board works correctly (see *Appendix C*).

5.2 IEC 61000-4-4 burst immunity test

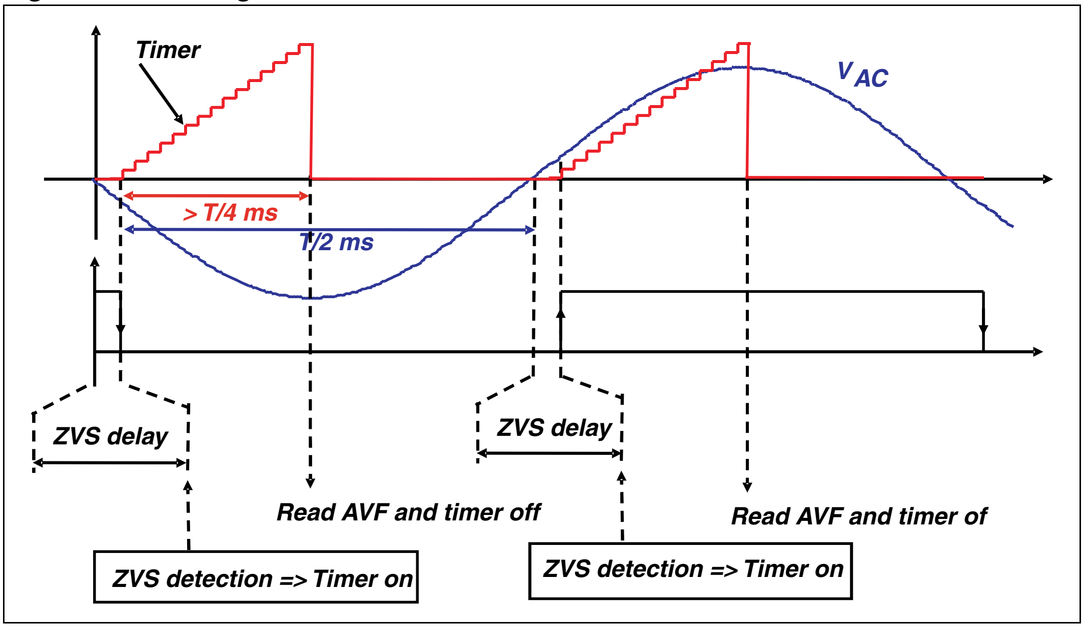
5.2.1 Test conditions

- Ambient temperature: 25°C
- Relative humidity: 35%

5.2.2 Demonstration board immunity test

The AC line input X2 capacitor C15 (10 nF) is used to help avoid triggering the AC switch (ACS108-6S). The MCU program reads the AVF signal at each AC line peak voltage (see *Figure 16*). The demonstration board is validated if the AVF signal remains at the same level during three consecutive AC line cycles.

Figure 16. AVF signal detection



The demonstration board and mains wires are placed 10 cm above the ground reference. The mains wire is shorter than 1 m. Each operating cycle has been tested (load off and on). The demonstration board supports burst levels higher than 4 kV without spurious triggering of the ACS or ST7Lite3 MCU loss whatever the coupling mode (to L, N, etc.).

5.2.3 Advice to improve the application immunity

To improve the application performance in term of EMC, the software must be EMC oriented (for more information please refer to the application note AN1015):

- **Auto-recovery routine.** At each reset interrupt, the program must check if the data stored in the RAM are as scheduled or not. A reset can occur without the supply voltage having fallen below V_{RM} (data retention parameter). In this case, a full start-up is not necessary, and the program can keep working with the previous RAM data. This is helpful to avoid missing load control and the AC switch status when a reset occurs due to an EMI problem, for example. If the checked RAM registers are not as expected, then a complete initialization procedure is launched. If the RAM area is adequate, then a “smart reset” can be performed. Only the registers that are used to store internal sub-routine variables are cleared. Only the main registers keep their previous values (AC switch status, AC switch control …).
- **Using the watchdog properly.** Enable the watchdog as soon as possible after reset and never refresh the watchdog in an interrupt routine.
- **Secure the unused program memory area.** Fill the unused memory locations with code that forces a watchdog reset or jumps to a known program location if you do not want to generate a reset.
- **Input filtering.** It is recommended that the AVF signal be read during several AC line cycles.

6 Conclusion

This application note illustrates how designers can maximize the STCC08 performance in their appliances especially for AC switch state detection and EMI robustness.

This document describes the STCC08 device and gives technical recommendations about the STCC08 implementation in the appliance.

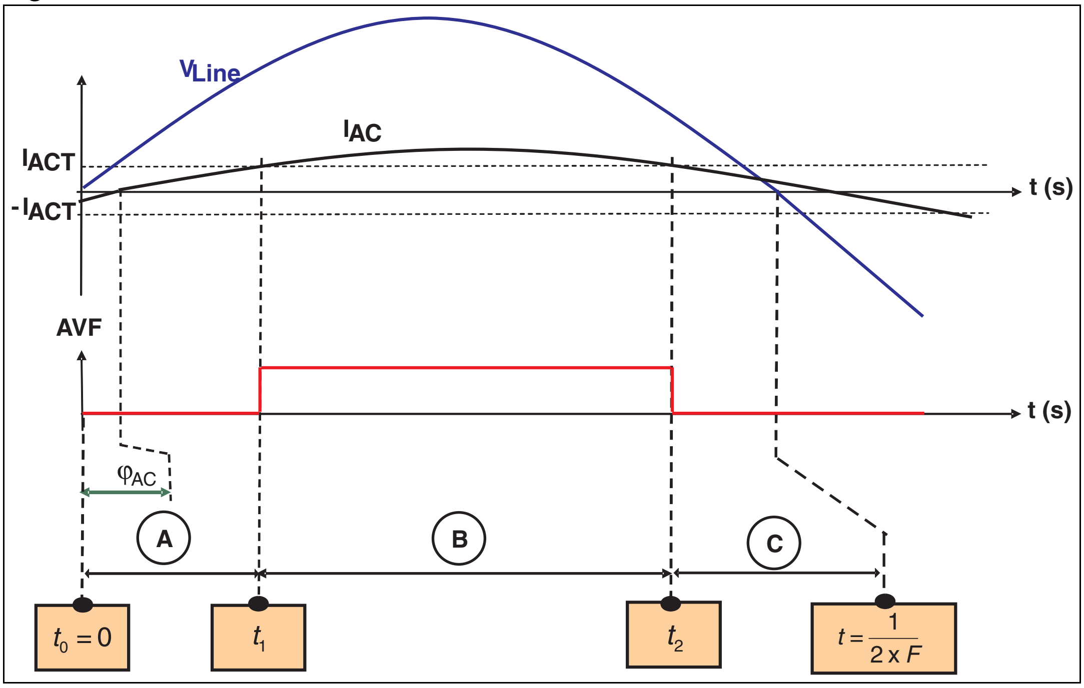
References

1. T. Castagnet, B. Cheron, A. Edet, “AC power management in homes appliances: a reality to save energy and increase safety”, IATC 2006, Rosemont, Illinois, USA.
2. L.Gonthier, "A New Solid State Switch for Home Appliances", International Appliance Technical Conference, IATC 1999, West Lafayette, Indiana, USA.
3. G. Benabdelaziz, P. Paillet, “AC STCC08 - Safety supervisor for home-appliance AC switches”, PCIM 2009, Nuremberg, Germany.

Appendix A Timing definitions

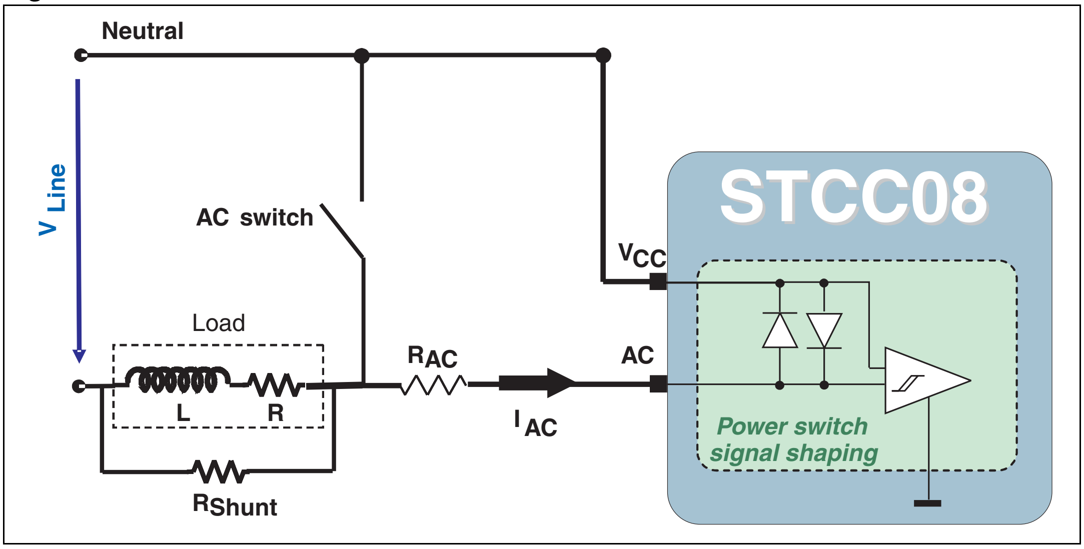
When the AC switch is OFF (not controlled or failed in open circuit), an IAC current flows through the STCC08 AC input. The value of this current depends on RAC and Rshunt resistors, the AC line voltage and the AC load impedance. The AVF signal toggles between VCC and zero level (GND) for an IAC current value noted IACT (see *Figure 17*).

Figure 17. Detection window width of the AC switch state



Considering *Figure 18*, the I_{AC} current variation, when the AC switch is off, is defined according to *Equation 11* where I_{AC_peak} is the peak I_{AC} current, F is the AC line frequency, R and L are AC load characteristics, and ϕ_{AC} is the phase shift between I_{AC} current and the AC line voltage.

Figure 18. AC load model definition



Equation 11

$$I_{AC}(t) = I_{AC\_peak} \cdot \sin(2 \cdot \pi \cdot F \cdot t - \varphi_{AC})$$

Considering *Equation 11*, t_1 and t_2 times are given respectively by *Equation 12* and *Equation 13* in the worst case (to avoid the false detection of an AC switch failed in short-circuit any time).

Equation 12

$$t_{1\_Max} = \frac{1}{2 \times \pi \times F_{min}} \cdot \left[Ar\ \sin\left(\frac{I_{ACT\_max}}{I_{AC\_Peak\_min}}\right) + \varphi_{AC\_max} \right]$$

Equation 13

$$t_{2\_min} = \frac{1}{2 \times \pi \times F_{max}} \cdot \left[\pi - \left(Ar\ \sin\left(\frac{I_{ACT\_max}}{I_{AC\_Peak\_min}}\right) + \varphi_{AC\_max} \right) \right]$$

$I_{AC\_peak\_min}$ defines the minimum peak I_{AC} current through the STCC08 AC input to ensure the AC switch state detection. This current must be higher than the maximum specified I_{ACT} parameter (I_{ACT_max}) in order to detect the AC switch state in the worst case (when the AC load is disconnected). *Equation 14* defines this condition. Indeed, when the AC load is disconnected, the I_{AC} current is limited by R_{AC} and R_{Shunt} resistors. For example, with $R_{AC} = R_{Shunt} = 300\ k\Omega$ (see *Equation 2* and *Equation 3*), F = 50 Hz and $V_{Line\_RMS\_min}$ = 230 V - 10%, the $I_{AC\_Peak\_min}$ is 465 µA.

Equation 14

$$I_{AC\_Peak\_min} = \frac{\sqrt{2} \cdot V_{Line\_rms\_min}}{R_{Shunt\_max} + R_{AC\_max}} > I_{ACT\_max\ (236\ \mu A)}$$

ϕ_{AC} is the phase shift between the AC line and the I_{AC} current when the AC switch is off. As the resistor R_{Shunt} value is higher than the most AC load impedances found in home appliances, this phase shift depends only on the AC load characteristic and resistor R_{AC}. *Figure 19* gives Fresnel's diagram for $R_{AC} = 0$ and $R_{AC} \neq 0$ for the circuit in *Figure 18* to define the ϕ_{AC} phase shift. If $R_{AC} = 0\ \Omega$, the rms I_{AC} current and ϕ_{AC} phase shift are equal respectively to rms I_{Load} current (I_{Load_RMS}) and ϕ_{Load} phase shift of the AC load. If $R_{AC} \neq 0\ \Omega$, the rms I_{AC} current (I_{AC_RMS}) and ϕ_{AC} phase shift depend on the value of the resistor R_{AC} and the AC load impedance. In this case, and according to Fresnel's diagram, the maximum ϕ_{AC} phase shift is defined by *Equation 15* and *Equation 16*.

Equation 15

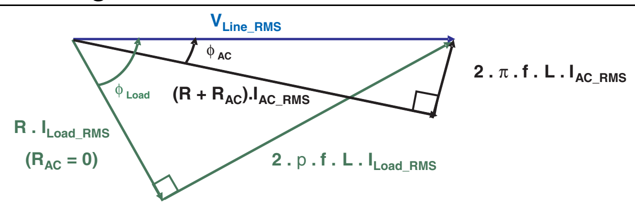
$$V_{Line\_rms} = \frac{L \times 2 \times \pi \times F \times I_{AC\_rms}}{\sin(\varphi_{AC})} = \frac{L \times 2 \times \pi \times F \times I_{Load\_rms}}{\sin(\varphi_{Load})}$$

Equation 16

$$\varphi_{AC\_max} = \mathrm{Arcsin}\left(\frac{I_{AC\_rms\_max}}{I_{Load\_rms\_min}} \times \sin(\varphi_{Load\_max})\right)$$

For example, in the worst case, if the minimum rms current (I_{Load_min}) and the maximum ϕ_{Load} phase shift of the AC load are respectively 0.1 A and 90°, the maximum ϕ_{AC} phase shift is about 1.26 °. This phase shift is very low and can be neglected as most AC loads have rms current higher than 0.1 A and phase shift lower than 90°. With $R_{AC} = R_{Shunt} = 300\ k\Omega$ and F = 50 Hz, t_{1_max} and t_{2_min} are respectively 1.7 ms and 8.3 ms.

Figure 19. Fresnel's diagram

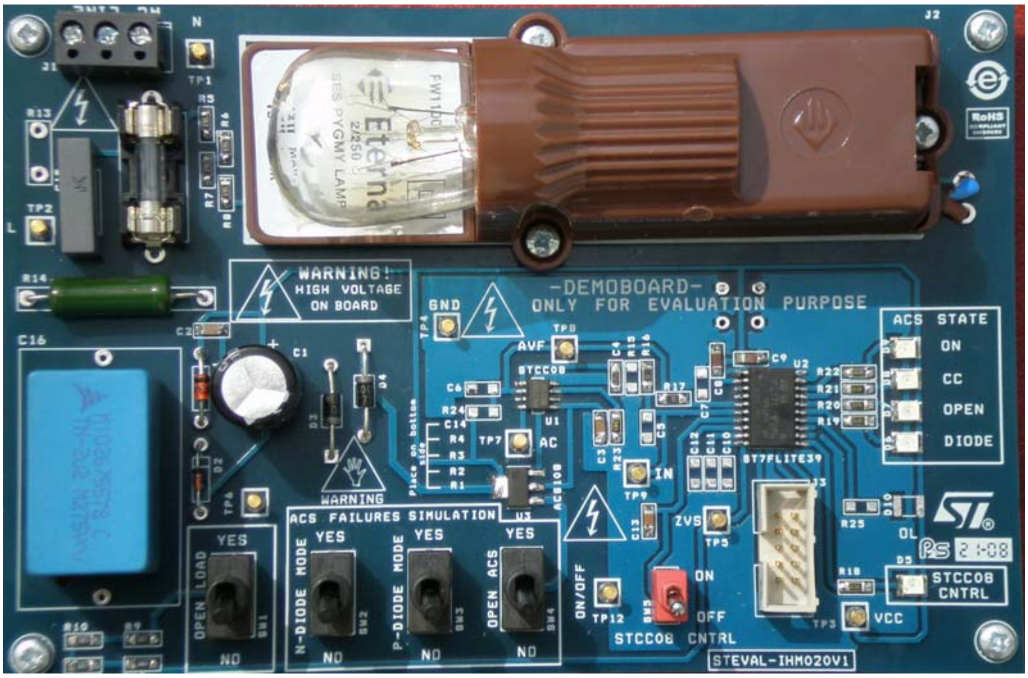


Note: *If the AC load is a resistor, or is disconnected, the I_{AC} current is in phase with the AC line ($\phi_{AC} = 0$).*

The STCC08 AVF signal should be read after the AC line peak voltage and before the t_2 time to detect all AC switch states for most home appliance loads.

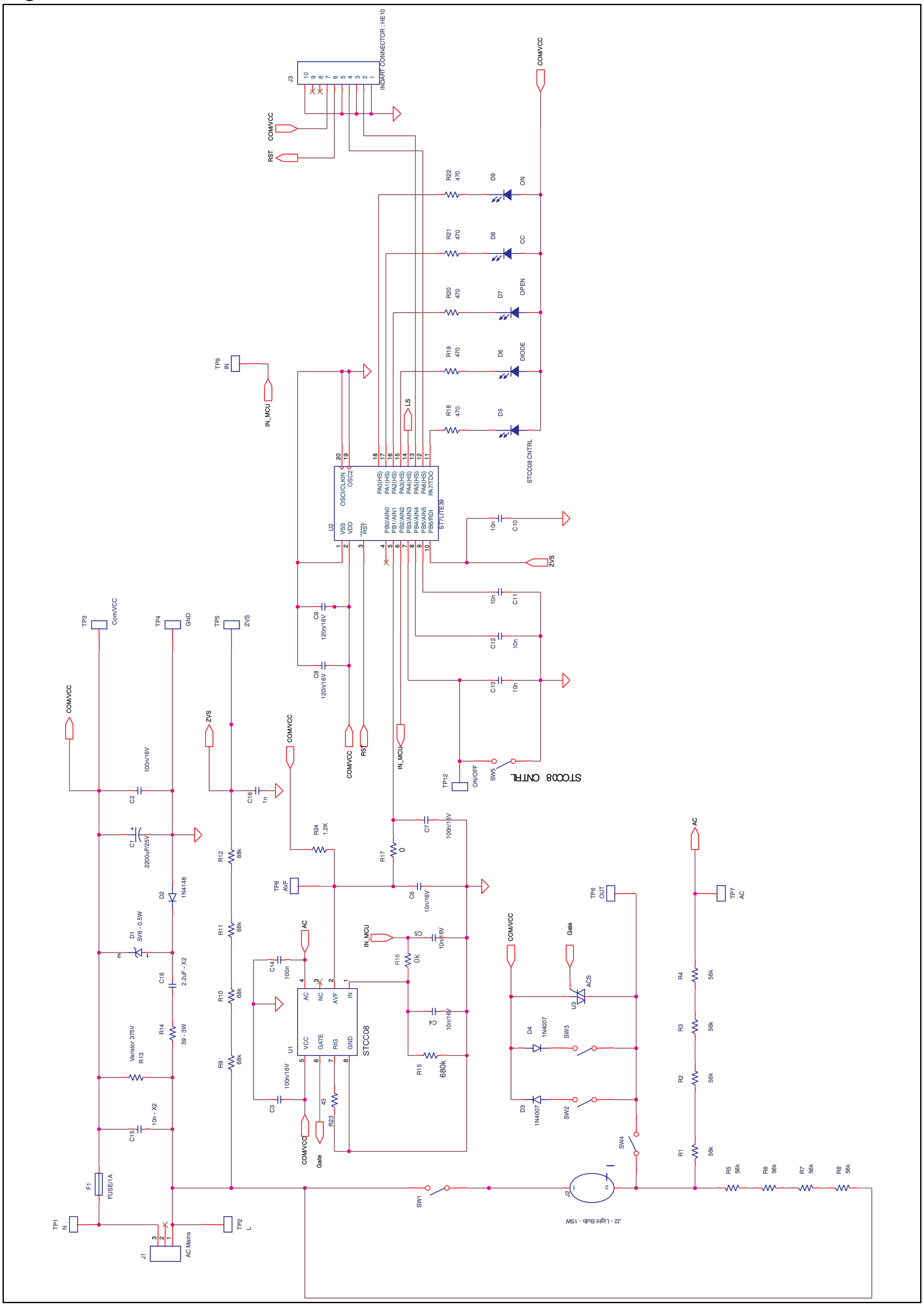
Appendix B Demonstration board component layout

Figure 20. Demonstration board component layout



Appendix C Demonstration board schematic

Figure 21. Demonstration board schematic



Appendix D Demonstration board circuit layout view

Figure 22. Top layer view

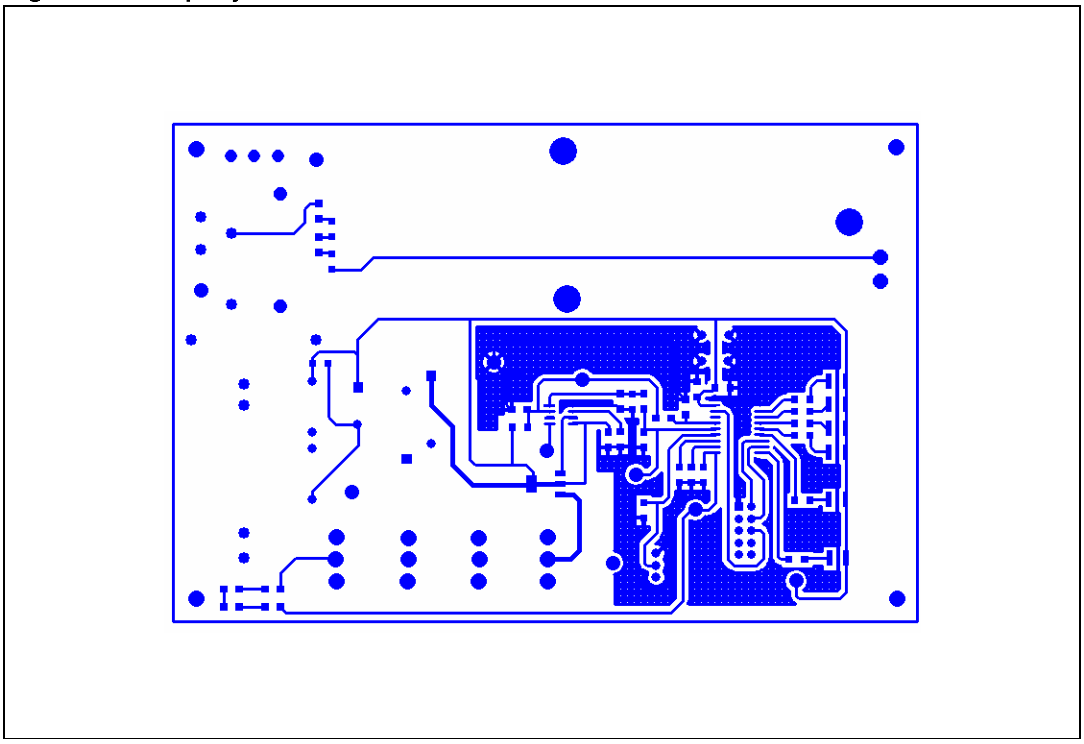
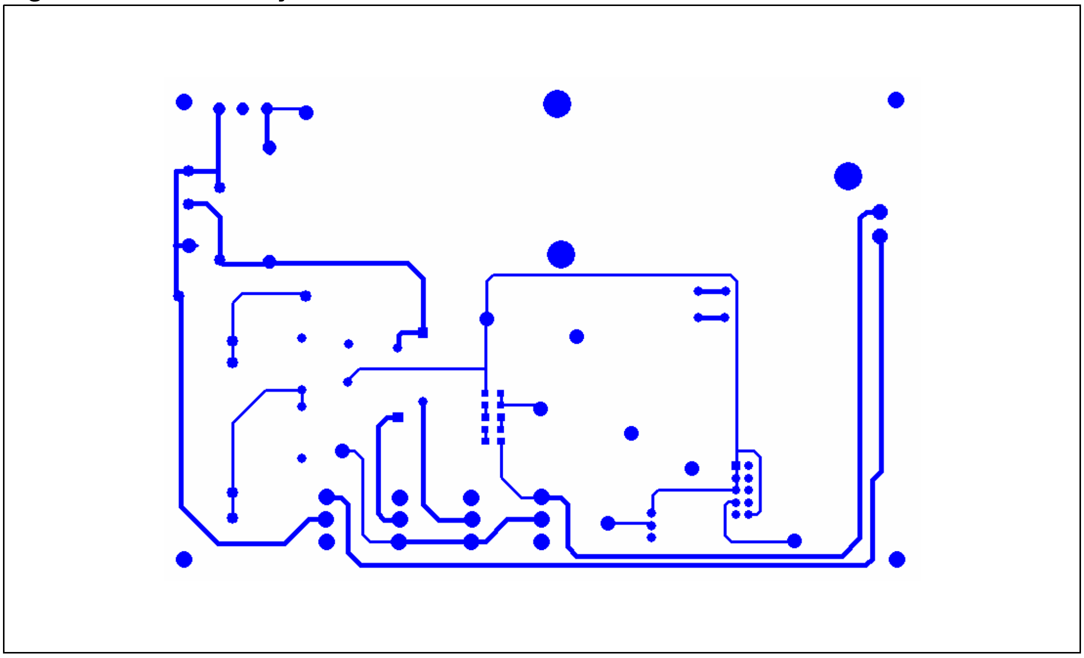


Figure 23. Bottom layer view



Revision history

Table 6. Document revision history

Date	Revision	Changes
26-Nov-2008	1	Initial release.
16-Jun-2010	2	Revised *Section 1.5.1* and *Appendix A*. Added *References*.