AN2863
Application note

Smart inductive proximity switch with SPT01-335DEE

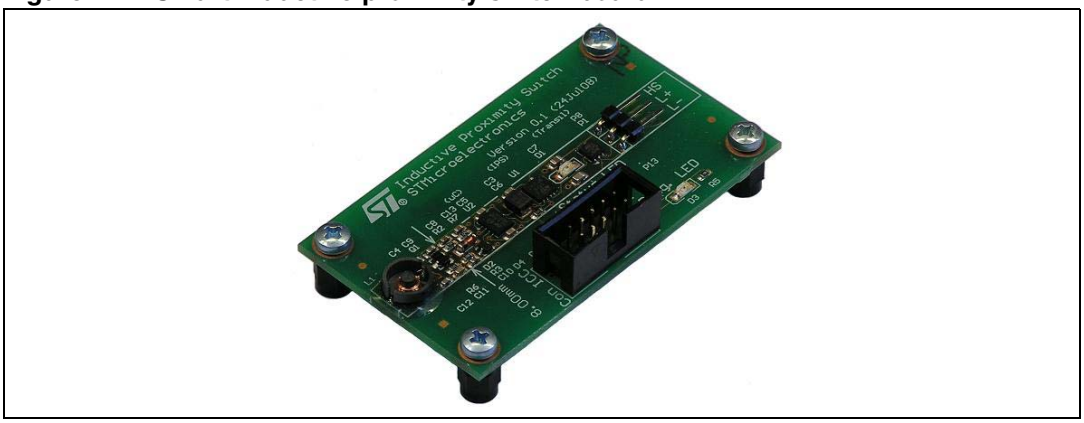
1 Introduction

The STEVAL-IFS006V2 demonstration board shows an inductive proximity switch based on the principle of metal body detection using the eddy current effect on the HF losses of a coil. It consists of a single transistor HF oscillator, a ST7LITEUS5 microcontroller, an intelligent TDE1708DFT power switch, and an SPT01-335DEE triple Transil™ array. The board demonstrates a very simple compact and cost-effective solution of an inductive proximity switch with regard to a wide temperature range, supply voltage variation, and noise immunity in industrial environments.

Features

- Metal body detection using the eddy current effect on the HF losses of a coil
- Good flexibility: MCU firmware can be modified depending on the application requirements - sensitivity and hysteresis adjustment
- In-circuit programming and in-circuit debugging capabilities
- Analog and digital temperature compensation
- PNP (high-side) sensor functionality configuration
- Complete Transil protection of the output and power supply lines
- Overload and short-circuit protection
- GND and Vs open wire protection
- Indicator status LED
- Compact design
- Supply voltage: 7 V to 32 V DC
- Temperature range: –25 °C to +85 °C.

Figure 1. Smart inductive proximity switch board



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2 Sensor overview

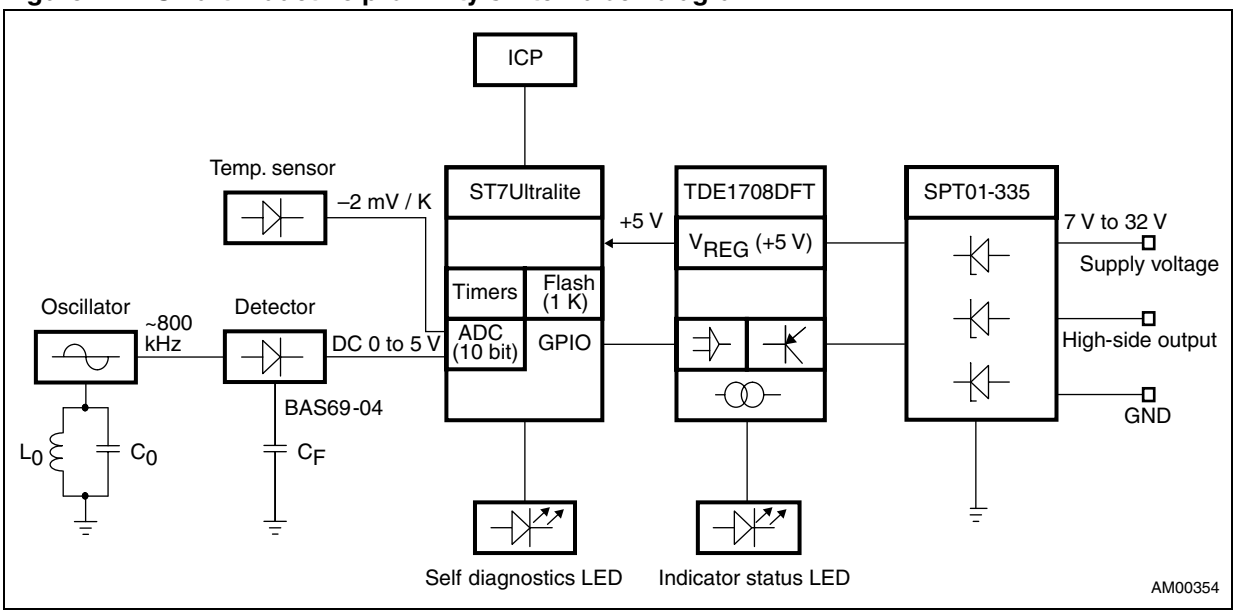
Proximity switches are generally applied to sense the position of a moving object in manufacturing processes. Typically, they utilize an oscillator drive circuit in combination with an induction tank circuit. The tank circuit includes an induction coil as a means for sensing the presence of an object such as metal. The magnetic field induces eddy currents in a conductive object which comes within the generated magnetic field. The oscillation amplitude is attenuated due to the energy drawn from the induction coil. The amount of the oscillation attenuation is directly related to the distance between the metal object and the induction coil.

A typical inductive proximity switch employs a ferrite cup core as the sensing element. It allows the flux field to be focused in front of the cup and further prolong the sensing distance. The oscillator usually operates between 100 kHz and 800 kHz, where the eddy current losses are significant.

Some benefits of the MCU approach compared with a traditional solution include:

- More reliable operation thanks to the sensor self diagnostics
- Easy and cheap sensor trimming in the production line
- Digital temperature compensation
- Linearization of the sensor characteristic
- Easy realization of an analog or a PWM output.

Figure 2. Smart inductive proximity switch block diagram



3 Sensor circuit description

The sensor HF oscillator circuit is based on the Colpitts oscillator type which has a simple circuit configuration, produces a very clean sinusoidal wave signal, and is capable of oscillating in a wide range of frequencies. The resonant circuit made up of the inductor L1 and capacitors C12, C9, and C8 determine the frequency of the oscillations according to *Equation 1*. The circuit actually oscillates at a slightly lower frequency due to the coupling capacitor C10, junction capacitances of the transistor Q1, and other stray capacitances.

Equation 1

$$f = \frac{1}{2\pi\sqrt{L_1\left(C_{12} + \frac{C_8 C_9}{C_8 + C_9}\right)}}$$

The oscillator employs a transistor Q1 operating in common base configuration which derives its feedback from the capacitor divider C9 and C8. Resistors R3 and R6 set its bias point and diode D2 temperature stabilizes it.

The oscillator signal amplitude is further detected by diodes D4 and D5 and filtered by capacitor C13. Together with C10, this circuit acts as a charge pump, therefore the full range of the ST7 ADC converter (0 V - 5 V) is used.

Another function of the diode D2 is temperature sensing. The voltage across a diode operated at constant current is linear in a very large range of temperatures and reduces with an increasing temperature with approximately –2 mV/K (see *Figure 7*). With the ST7 10-bit ADC converter, the temperature can be measured with the resolution of approximately 2.5 °C which is enough for the overall correction of the sensor temperature variations (see *Figure 6*).

The output power stage of the sensor is equipped by the intelligent TDE1708DFT power switch integrating overload and short-circuit protection, GND and Vs open wire protection, +5 V linear regulator, indicator status LED driver, and many other functions.

The triple Transil array SPT01-335DEE realizes the overall protection of the sensor. This device was specially developed for 24 V proximity sensors. It provides a very compact solution for the efficient protection of bus, output power switch, and power supply reverse blocking. Demagnetization of an inductive load is another key feature.

3.1 Initial configuration

Figure 3 shows the initial demonstration board configuration in relation to the power supply and the load. Compared to the previous version of this board (STEVAL-IFS006V1) this new board only supports the more frequently used PNP (high-side) output driver configuration, although the intelligent TDE1708DFT power switch and the triple Transil array SPT01-335DEE support both. The reason for this is the number of necessary jumpers needed for functionality change.

3.2 ICC connector

The board ICC connector offers in-circuit programming and in-circuit debugging capabilities and therefore simplifies the firmware development. More information about ST7 development tools is available at www.st.com/mcu.

Figure 3. Initial configuration

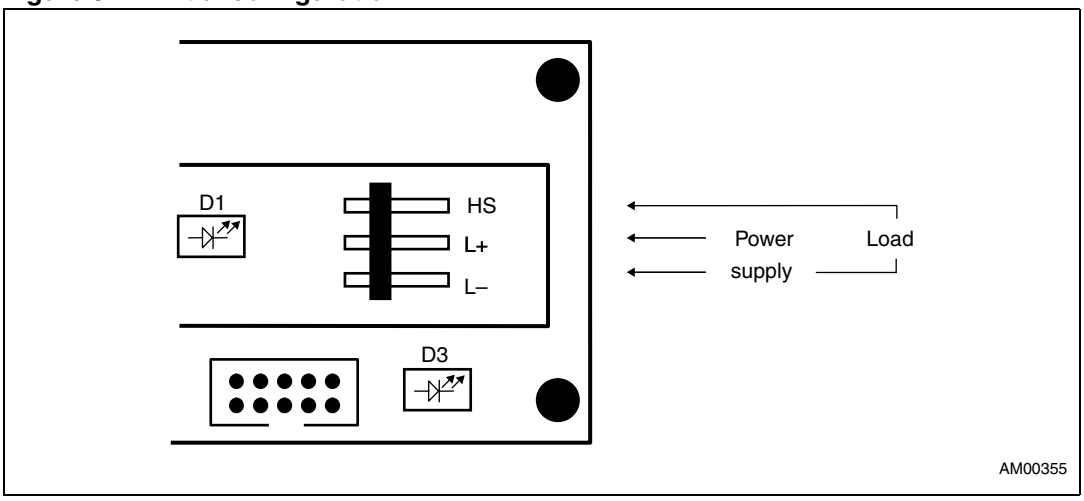


Figure 4. Application schematic

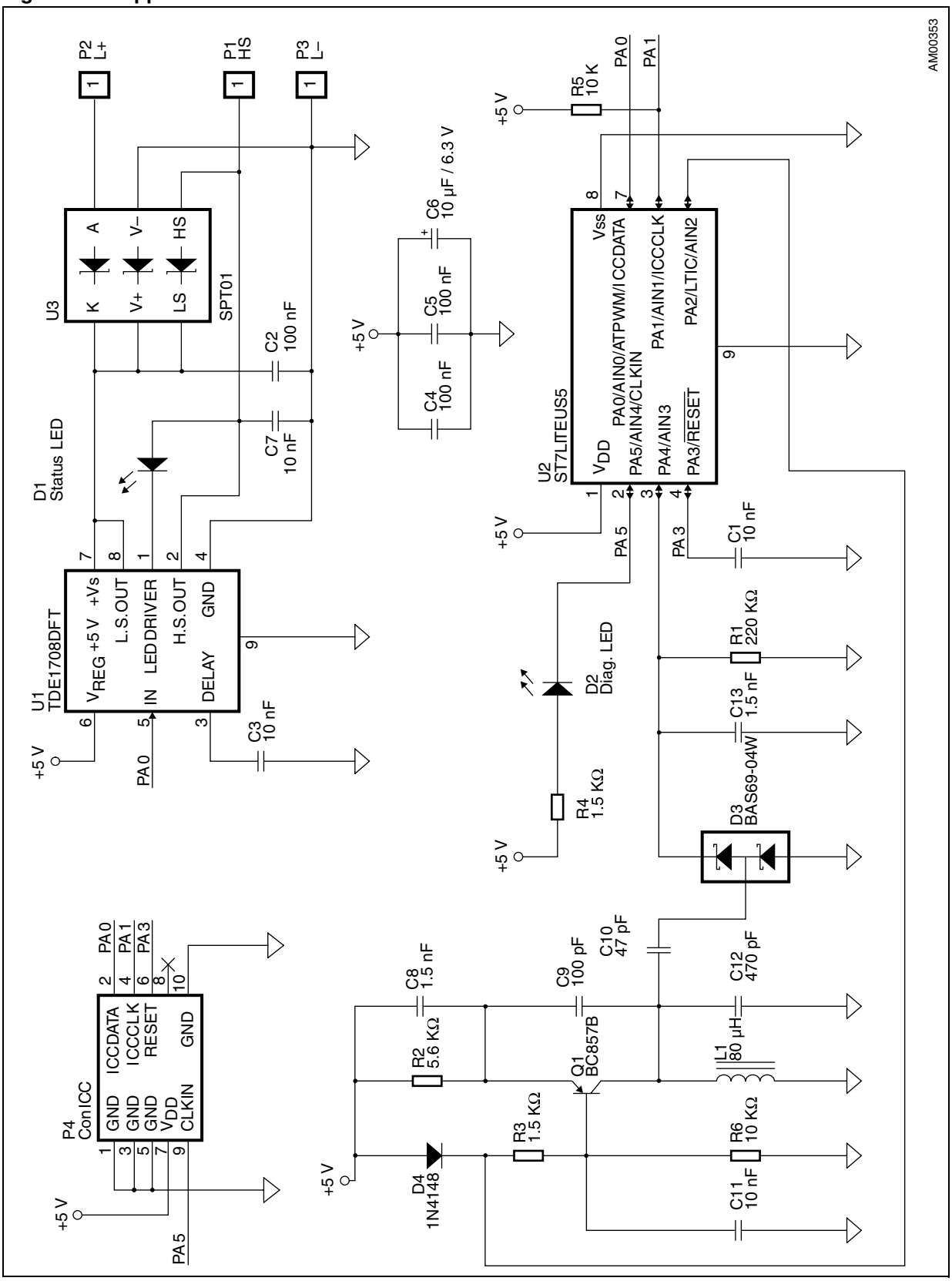


Table 1. Bill of material

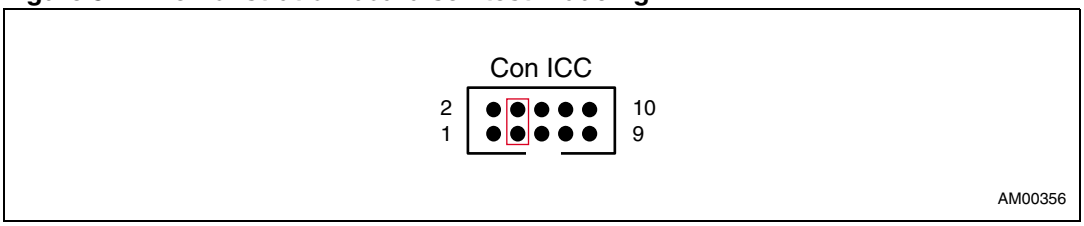
Reference	Value	Description	Quantity	Supplier	Order code
U1	TDE1708DFT	Intelligent power switch	1	STMicroelectronics™	TDE1708DFT
U2	ST7LITEUS5	8-bit MCU	1	STMicroelectronics	ST7FLITEUS5U3
U3	SPT01-335DEE	Triple Transil array	1	STMicroelectronics	SPT01-335DEE
C1, C3, C11	10 nF	Capacitor	3	EPCOS	B37931A5103K0
C2	100 nF	Capacitor	1	EPCOS	B37941A5104K0
C4, C5	100 nF	Capacitor	2	EPCOS	B37931K0104K0
C6	10 µF / 6.3 V	Polarized capacitor	1		
C7	10 nF	Capacitor	1	EPCOS	B37941A1103K0
C8, C13	1.5 nF	Capacitor	2	EPCOS	B37931A5152K0
C9	100 pF	Capacitor	1	EPCOS	B37930A5101J0
C10	47 pF	Capacitor	1	EPCOS	B37930A5470J0
C12	470 pF	Capacitor	1	EPCOS	B37930A5471J0
D1	Status LED	LED	1		
D2	Diag. LED	LED	1		
D3	BAS69-04W	Schottky barrier double diode	1	STMicroelectronics	BAS69-04W
D4	1N4148	High conductance fast diode	1		
L1	80 µH	PS-core inductor	1	BOHEMIA ELECTRIC	BS361
P1	HS	Header, 1-pin	1		
P2	L+	Header, 1-pin	1		
P3	L–	Header, 1-pin	1		
P4	Con ICC	ICC connector	1		
Q1	BC857B	PNP transistor	1		
R1	220 KΩ	Resistor	1		
R2	5.6 KΩ	Resistor	1		
R3, R4	1.5 KΩ	Resistor	2		
R5, R6	10 KΩ	Resistor	2		

4 Software implementation

After the first startup following the firmware upload, the ST7 MCU performs a simple board self test. It reads the oscillator amplitude level and voltage across the temperature sensing diode D2 and checks whether these values are in a specific range (this state is indicated by diagnostic LED D3 blinking, see *Table 2*). The oscillator amplitude level detected during this test is also considered as an initial oscillator level when no metal object approaches the sensing inductor L1 and its value is recorded in the Flash memory (address 0xfc00) using the in-application programming (IAP) method. This value is later used for amplitude reduction comparisons caused by metal objects.

Note: The initial board self test procedure can be induced anytime by placing a jumper on the ICC connector (pins 3-4, see Figure 5) and powering up the application.

Figure 5. Demonstration board self test inducing



During normal operation the MCU controls the sensor output based on the information regarding the oscillator amplitude and the actual temperature. The main sensor part of the firmware is realized in an auto-reload timer interrupt service routine. In equi-distant time intervals the oscillator amplitude is sampled and its value is compared with two system variables (ucUpperCompThreshold and ucLowerCompThreshold). One of these defines on-to-off transition while the other defines off-to-on transition of the sensor state. The distance between them determines the hysteresis. These threshold variable values are defined as a percentage of the initial oscillator level recorded in the Flash memory and are further modified depending on the temperature by a co-efficient from a lookup table.

Table 2. Diagnostic LED blinking modes (power up self test)

LED status	Meaning
Blinking	Input values within limits
Constant	Error

Table 3. Diagnostic LED blinking modes (normal operation)

Flashing style	Meaning
* * * * * *	Undertemperature
** ** ** **	Overtemperature
*** *** ***	Ferrite approaching the coil

Figure 6. Oscillator amplitude vs. temperature (MCU pin 3)

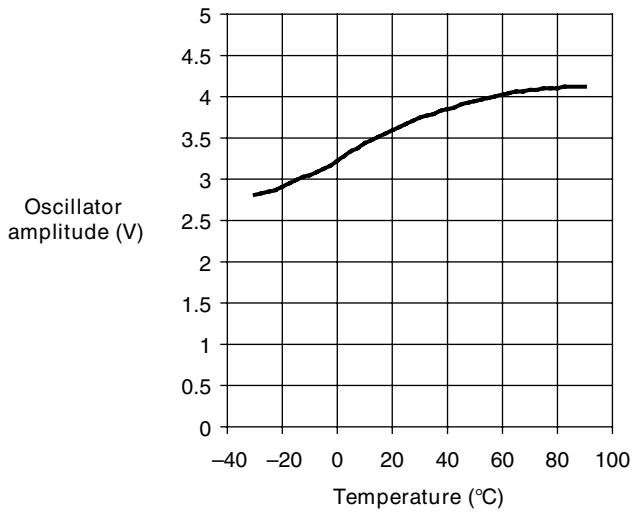
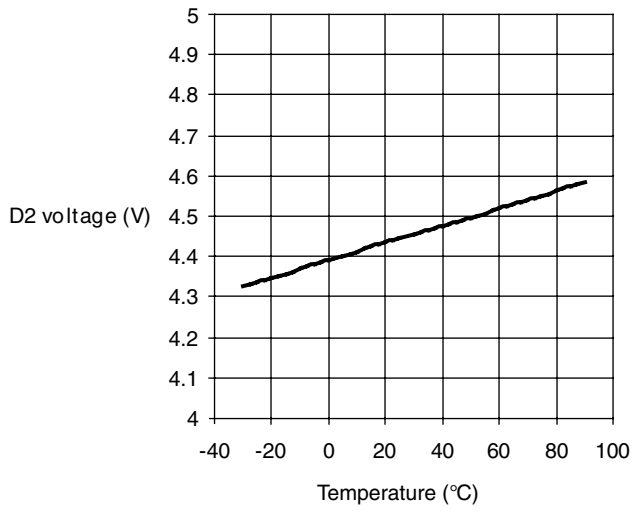


Figure 7. D2 voltage vs. temperature (MCU pin 5)



5 References

1. ST7LITEUSx datasheet.
2. TDE1708DFT datasheet.
3. SPT01-335DEE datasheet.
4. BAS69-04W, see BAS69 datasheet.
5. AN495 application note.
6. EN60947-5-2; *Low-voltage switchgear and controlgear - Part 5-2*: Control circuit devices and switching elements - Proximity switches".

6 Revision history

Table 4. Document revision history

Date	Revision	Changes
10-Feb-2010	1	Initial release.

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