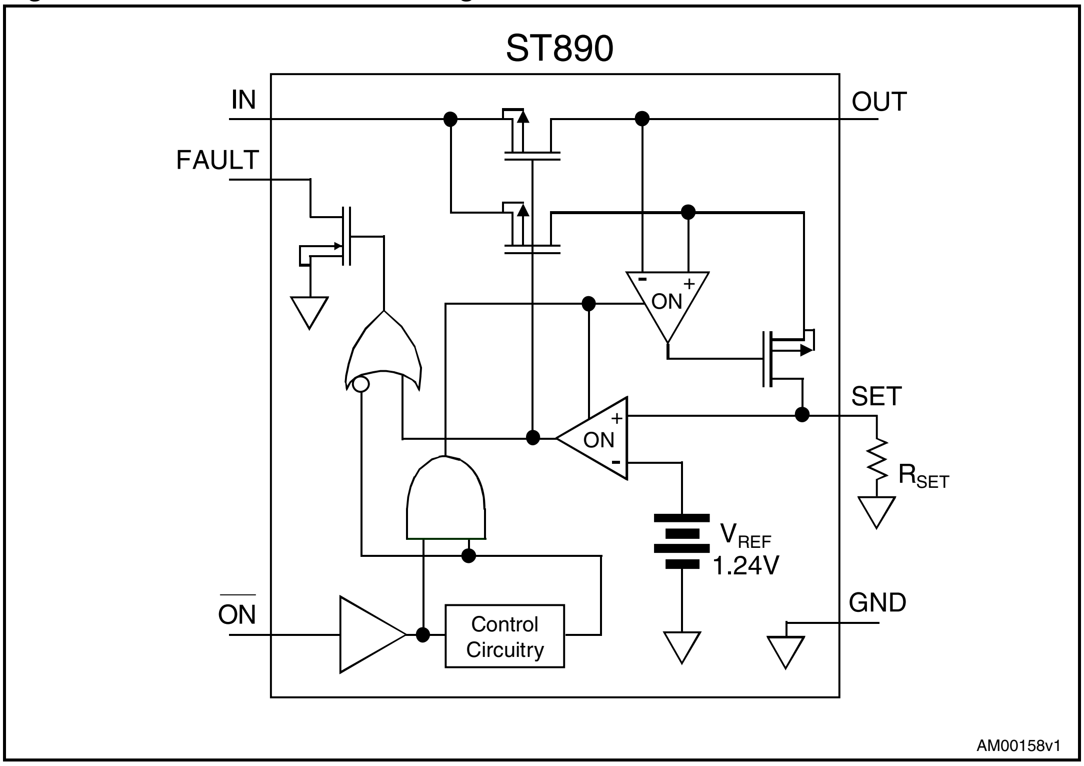
AN1441
Application note

ST890: a high side switch
for PCMCIA and USB applications

Introduction

The ST890 is a low voltage, P-channel MOSFET power switch, intended for high side load switching applications. Its main applications are PCMCIA slots, portable equipment and access bus slots. The device is useful in all the applications that need a supply with short-circuit protection and programmable current limitation, such as slots in which cards can be connected and disconnected without turning off the power supply.

Figure 1. ST890 internal block diagram



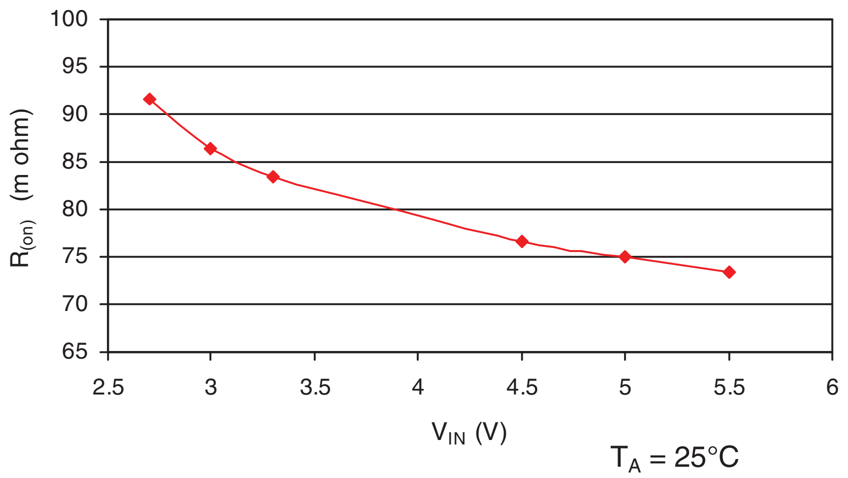
1 Functional description

1.1 Switch resistance

The internal block diagram of the ST890 is shown in *Figure 1*. The high side power MOSFET, used as a switch, has an R_{ON} lower than 90 mΩ at V_{CC} = 3.0 V. In the case of a load current of 1 A, the drop voltage between the IN and OUT pins is lower than 1 A x 0.1 Ω = 0.1 V and, for a switch, it is very important to keep this drop voltage low.

Figure 2 displays the R_{ON} versus the V_{IN} supply voltage. The R_{ON} depends on the V_{IN} because the P-channel MOSFET is driven by the V_{OUT} of the internal error amplifier.

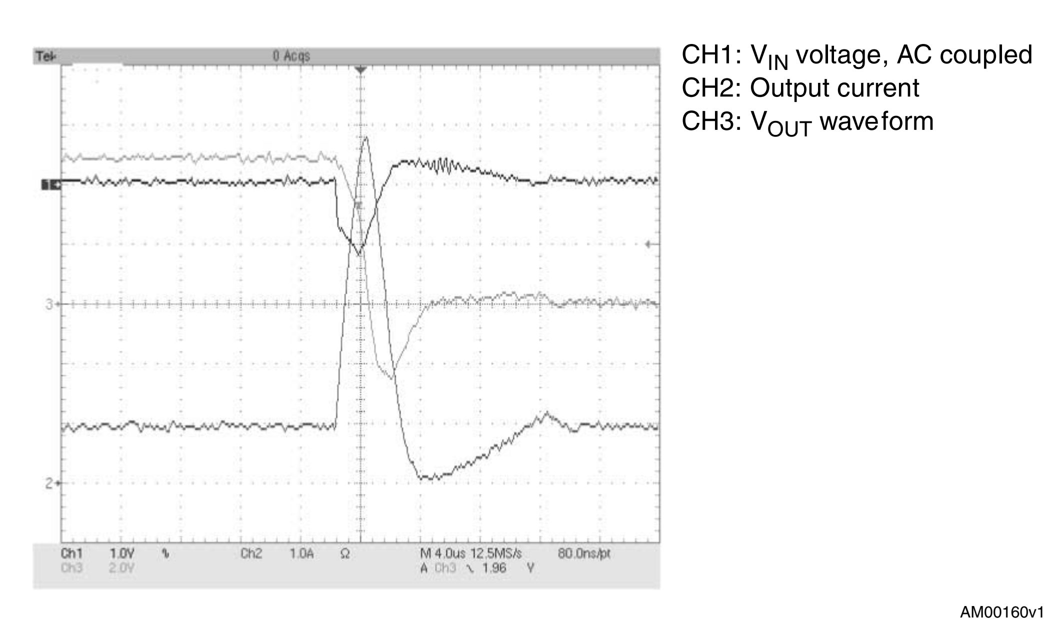
Figure 2. ON resistance vs. V_{IN} supply voltage



1.2 Short-circuit protection

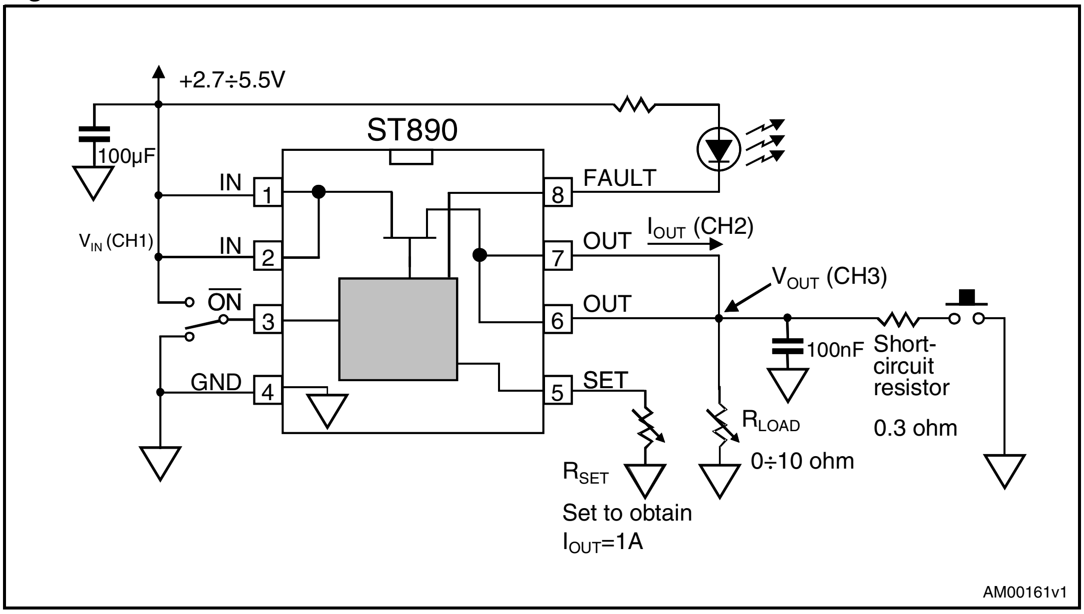
The low resistance of the MOS channel is important. However, the control circuitry that must quickly drive the MOS to provide enough V_{GS} voltage to turn on the MOS channel, has greater importance. If the control circuitry does not drive the MOS quickly enough, the current of the card could be broken, as shown in *Figure 3: ST890 in a short-circuit condition*.

Figure 3. ST890 in a short-circuit condition



When in normal function, the OUTPUT current, divided by 1110 by the current mirror circuitry (see *Figure 1*), flows in the external R_{SET} resistor creating a V_{SET} voltage. V_{SET} is compared to the internal reference voltage (1.24 V), and the error amplifier provides the V_{GS} voltage to drive the high side P-channel MOSFET. Due to this feedback, it is possible to limit the output current at I_{LIMIT}. When a short-circuit occurs, the V_{SET} drops because of the internal current mirror and the V+ input of the error amplifier becomes lower than 1.24 V (internal reference voltage). In this case the error amplifier cannot work in the linear area and current control is not possible. To ensure current limitation, even in short-circuit conditions, the error amplifier is supported by a correction circuitry and the result is shown in *Figure 3*. After the rising of the output current, the feedback circuitry begins to run and the output current is then equal to or less than 1.2 times the I_{LIMIT} value. This measurement was taken with the test circuit seen in *Figure 4*.

Figure 4. Test circuit



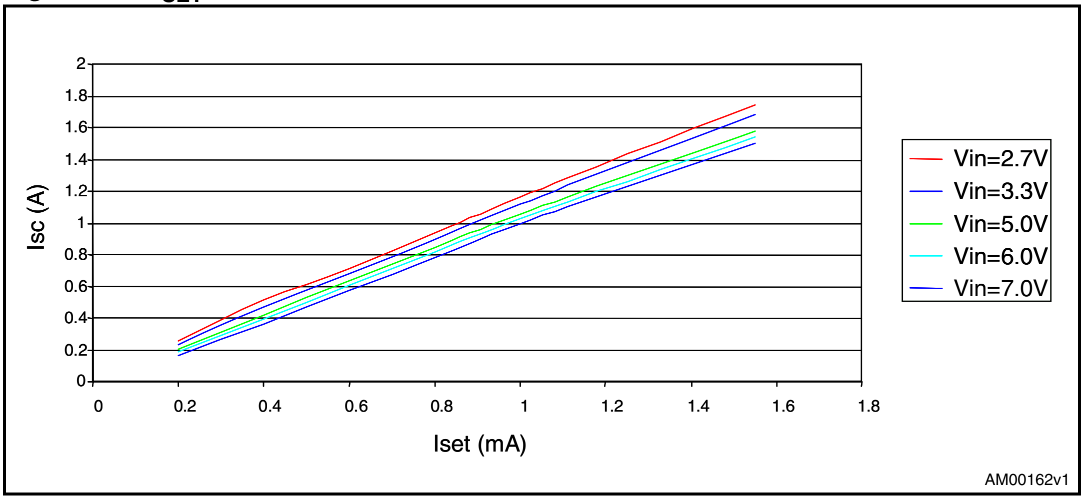
Note: To take this measurement, the input capacitor is 100 µF instead of 1 µF. Typically, a 1 µF input capacitor, like in the demonstration board circuit, is sufficient.

R_{SET} is calculated to obtain I_{LIMIT} =1 A and R_{LOAD} is set to have 1 A to GND. To generate the short-circuit condition, the switch on the right side of *Figure 4* was used.

1.3 Programming the current limit

The ST890 current limit can be programmed with the SET pin. This pin is internally connected both to the current mirror, which divides the I_{OUT} by 1110, and to the error amplifier (*Figure 1*) which calculates the difference between the reference voltage and the voltage V_{SET} of the SET pin. *Figure 5* shows the I_{LIMIT} vs. I_{SET} curve.

Figure 5. I_{SET} vs. ISC characteristics



The formula to calculate R_{SET} is:

$R_{SET} = V_{SET} / I_{SET}$ $I_{SET} = I_{LIMIT} / 1110$

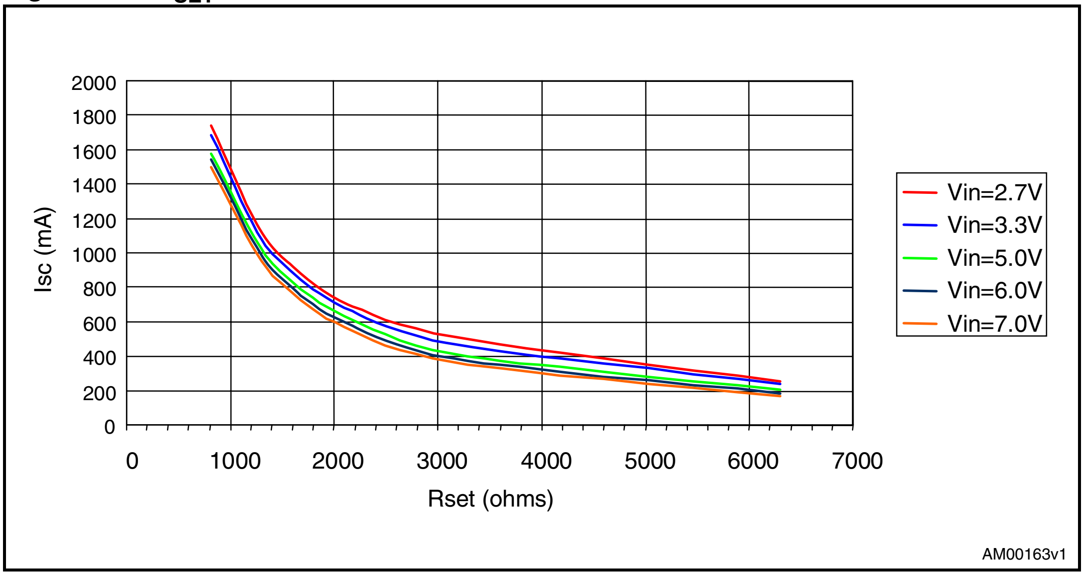
then:

$R_{SET} = 1.24 \times 1110 / I_{LIMIT}$

where V_{SET} is the pin 5 voltage; in the case of current limitation, this voltage corresponds to the internal V_{REF} (see *Figure 1*). I_{SET} is the current flowing into the R_{SET} resistor.

Figure 6 shows the programmable current range joined with the R_{SET}. The minimum ISC value is up to 200 mA.

Figure 6. R_{SET} vs. ISC characteristics



1.4 Fault

The FAULT pin (pin 8) is an open drain output useful to warn the microprocessor that a fault condition has occurred. The fault condition starts in the following conditions:

– if the I_{OUT} current exceeds the I_{LIMIT} value set

– if a short-circuit occurs

– if the devices goes in thermal protection

The FAULT pin should be connected to the IN pin (V_{CC}) by a 100 k pull-up resistor. This N-channel MOSFET can drive a LED in pull-up configuration as shown in *Figure 4: Test circuit*. In a typical USB application the ST890 typically supplies a load up to 44 Ω in parallel with 10 µF that represents any bypass capacitor directly connected across the power USB line. When the power switch is turned ON, an inrush current flows through the capacitor and causes an unwanted FAULT warning signal, as seen in *Figure 7*. To avoid the controller going into an alarm state, an RC filter can be placed on the FAULT pin, as seen in *Figure 8*.

Figure 7. Fault signal when an inrush condition occurs

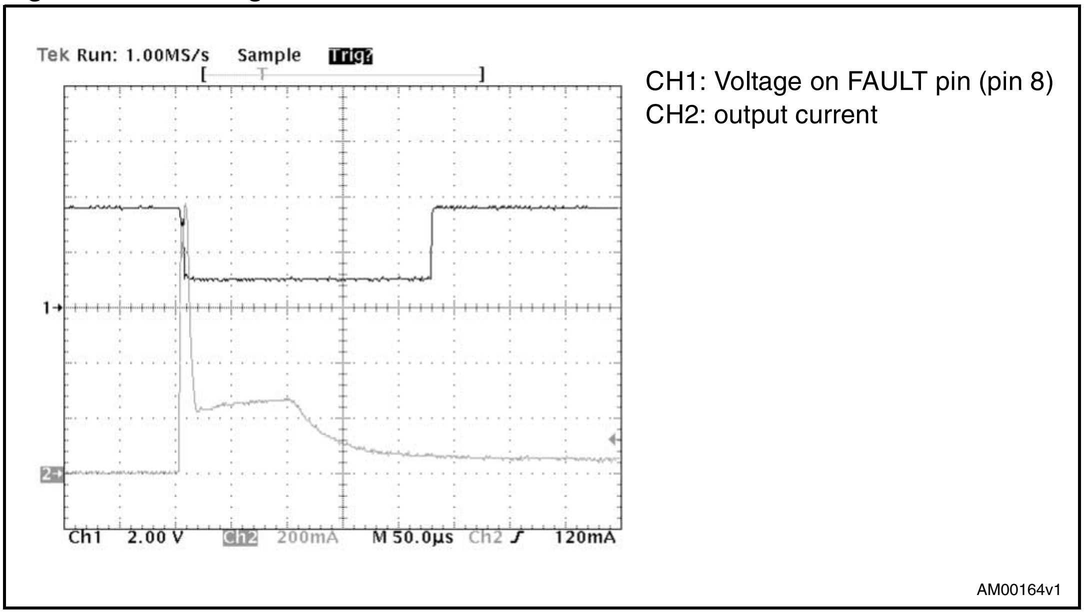
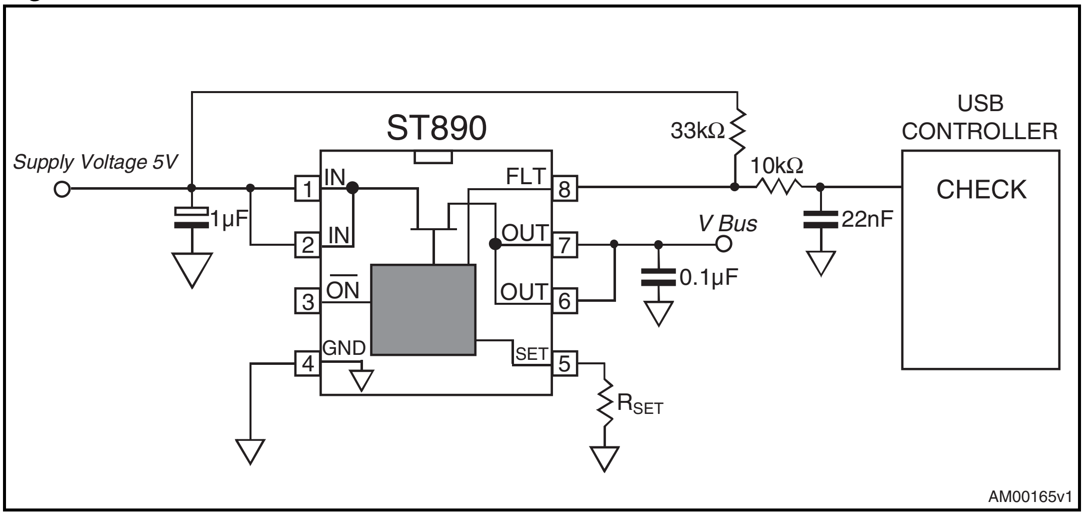
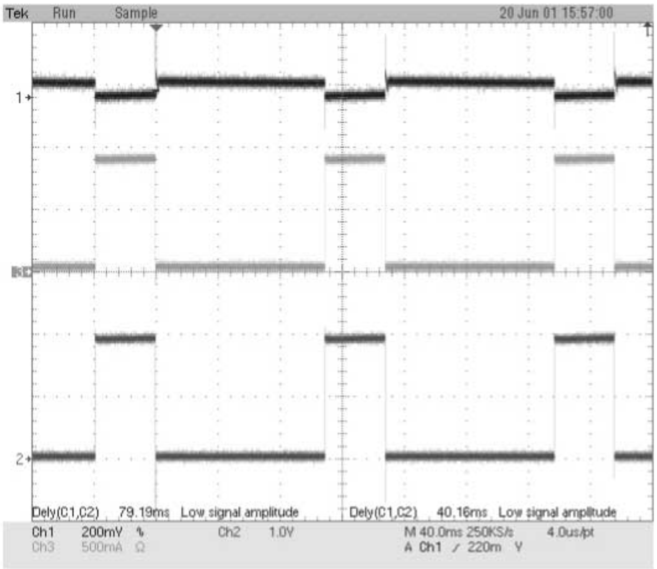


Figure 8. Filter for the FAULT transients



1.5 Thermal protection

Figure 9. Thermal protection behavior



CH1: V_{IN} voltage, AC coupled
CH2: V_{OUT} waveform
CH3: Output current

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Thermal protection occurs when the junction temperature exceeds 135 °C and the thermal hysteresis is 15 °C. This feature safeguards the device from dangerous currents or temperatures. *Figure 9* shows the thermal protection behavior. The pulse width and period of the output current depend on the thermal dissipation. This test was made in a free air temperature condition.

1.6 $\overline{\text{ON}}$ Pin Function

Figure 10. Turn-on time

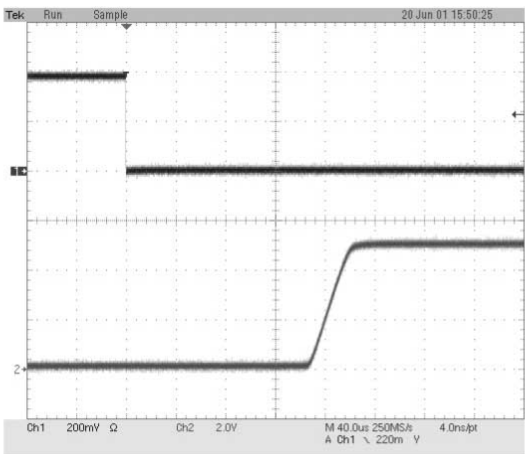

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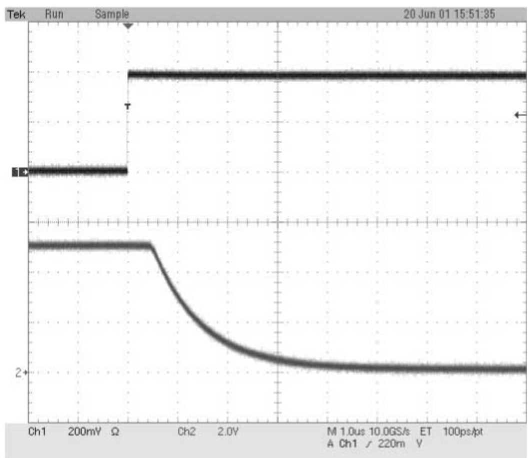
Figure 11. Turn-off time



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The $\overline{ON}$ pin switches over the N-channel MOSFET. *Figure 10* and *11* respectively show the turn-on and turn-off times.

2 Application information

The ST890 application circuit needs few external components.

2.1 Power supply filtering

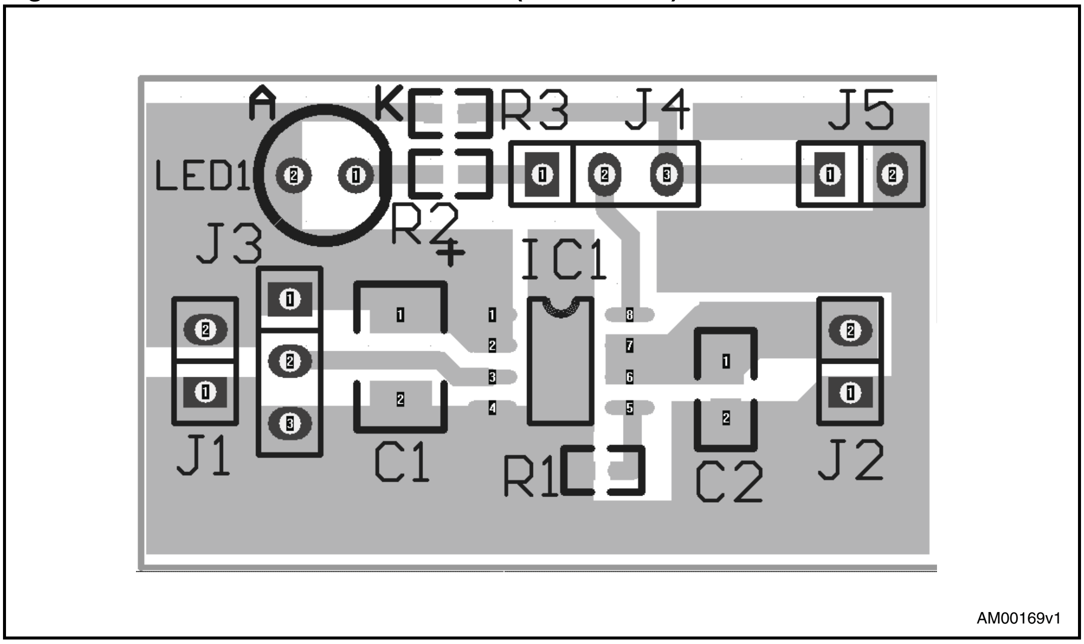
A 1 µF capacitor to GND can be placed at the input to reduce the drop voltage during switching and short-circuit events. On the OUT pin to GND, a 100 nF capacitor filters the output signal. For example, *Figure 10* and *11* show the output voltage in a switching condition, with a load-sinked current of 500 mA. In order to improve the performance of the ST890, the filter capacitors should be placed near the pins.

2.2 PCB rules

Regarding the PCB (printed circuit board), some rules should be followed: the IN and OUT pins should be connected using a large metal area to reduce the wire resistance and to reduce the drop voltage between IN and OUT. The SET, FAULT and $\overline{ON}$ pins are not critical.

2.3 PCB thermal dissipation

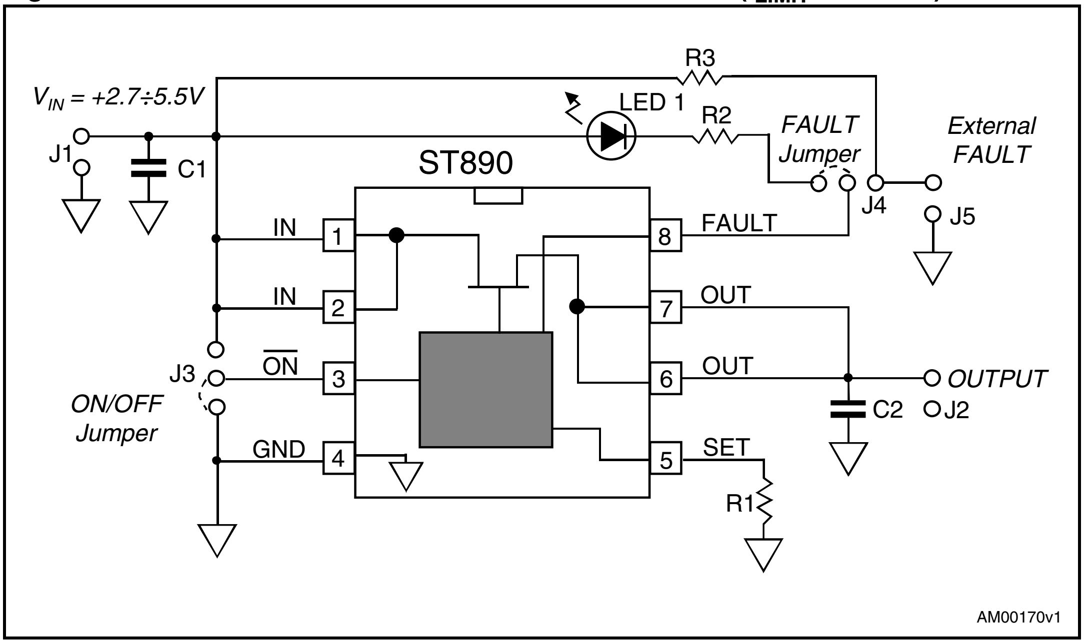
Figure 12. ST890 demonstration board (not to scale)



A ground plane is useful when improving the power dissipation of the ST890 device. In normal conditions the package used for the ST890 device, the SO-8, can dissipate the power produced by the I_{LIMIT} current that flows through the switch, $P = I^2_{LIMIT} \times R_{ON}$. This power is also equivalent to $P = V^2_{SW}/R_{ON}$, where V_{SW} is the drop voltage of the switch in ON state. When the OUT pin is shorted to GND the V_{SW} increases as well as the power and the junction temperature. This temperature, which continually increases until the thermal protection occurs, can be dissipated with a ground plane, as shown in *Figure 12*. *Figure 12* and *13* display the demonstration board PCB and schematic circuit. It is designed for SMD components.

2.4 Demonstration board description

Figure 13. ST890 demonstration board schematic circuit (I_{LIMIT} = 500 mA)



On the left side of the board the power input connector is found, while the output connector is on the right side. A 3-pin connector, J3, is located on the left side as well. This connector uses a “jumper” that connects together GND or V_{IN} to turn the switch ON or OFF. The FAULT pin (pin 8) is connected to J4. It can be closed by using the jumper to reach LED1, or it can be used to connect the FAULT to an external microprocessor. The SET pin (pin 5) is connected to GND through a resistor R1 to set the I_{LIMIT}.

The bill of material is:

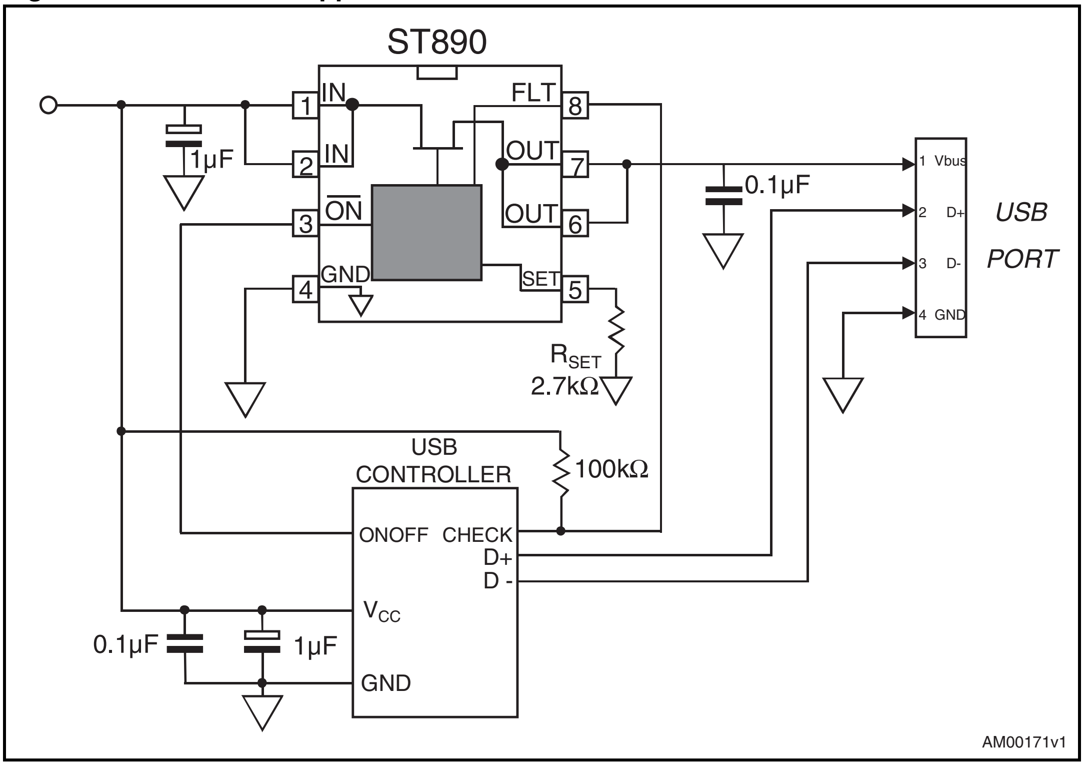
– R1 = 2700 Ω 1/4 W (to set I_{LIMIT} = 500 mA)
– R2 = 680 Ω 1/4 W
– R3 = 100 kΩ 1/4 W
– C1 = 1 µF
– C2 = 0.1 µF
– IC1 = ST890
– LED1 = 3 mm LED
– J1-J5 = straight pin headers

2.5 ST890 and USB bus

An example of a ST890 application is the supply of a USB bus, as seen in *Figure 14: ST890 USB application*.

Few components are required with the ST890. R_{SET} is 2.7 kΩ in order to obtain an I_{LIMIT} of 500 mA, and the filtering capacitance is used to filter the power supply IN and OUT. The USB controller is used to control the switch, check the V_{BUS} condition through the FLT pin and drive the USB data line (D+ and D-). Even the ST7263 microcontroller could be used.

Figure 14. ST890 USB application



3 Revision history

Table 1. Document revision history

Date	Revision	Changes
15-Oct-2003	1	Initial release.
22-Apr-2009	2	Document reformatted. Watermark removed from all pages. Content reworked to improve readability, no technical changes.

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