

## ST890: A HIGH SIDE SWITCH FOR PCMCIA AND USB APPLICATIONS

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### 1. INTRODUCTION.

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. ST890 is useful in all the applications that need a supply with short-circuit protection and programmable current limitation, like the slots in which the cards can be connected and disconnected without turning off the power supply.

### 2. FUNCTIONAL DESCRIPTION.

#### 2.1. Switch Resistance.

Figure 1 shows the internal block diagram of the ST890. The high side Power MOSFET, used as a switch, has an  $R_{ON}$  lower than  $90m\Omega$  at  $V_{CC}=3.0V$ . In the case of a load current of 1A, the drop voltage between the IN and OUT pins is lower than  $1A \times 0.1\Omega = 0.1V$  and, for a switch, it is very important to keep this drop voltage low.

Figure 1: ST890 Internal Block Diagram

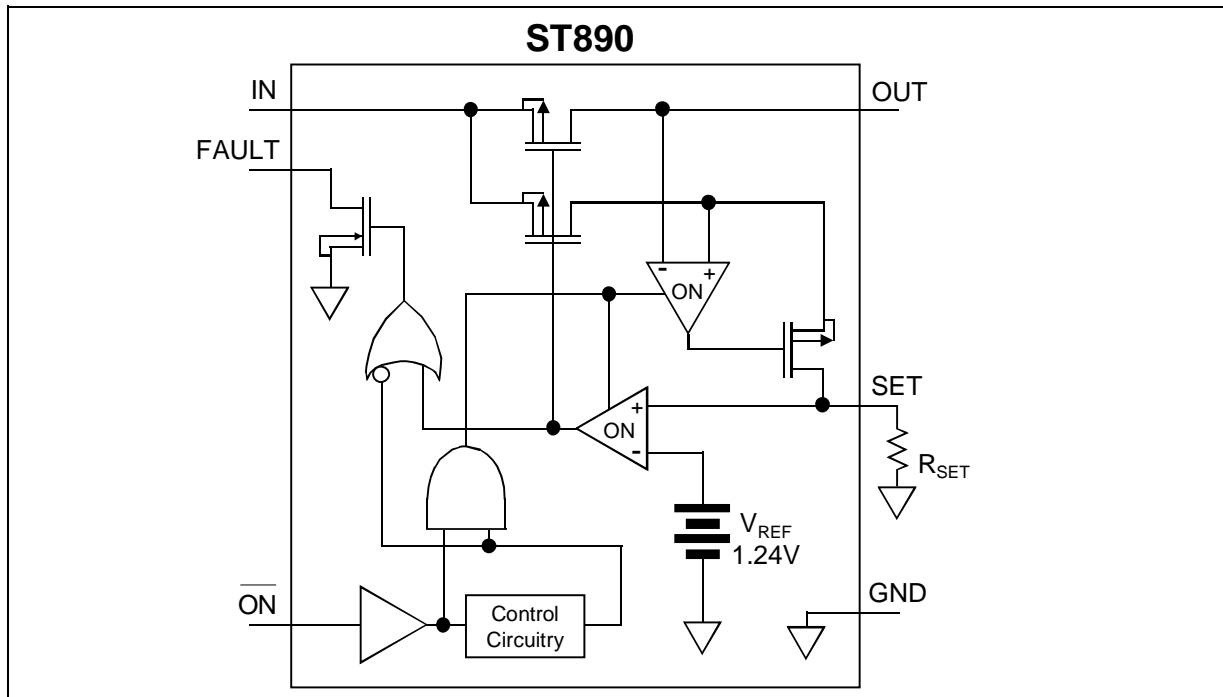
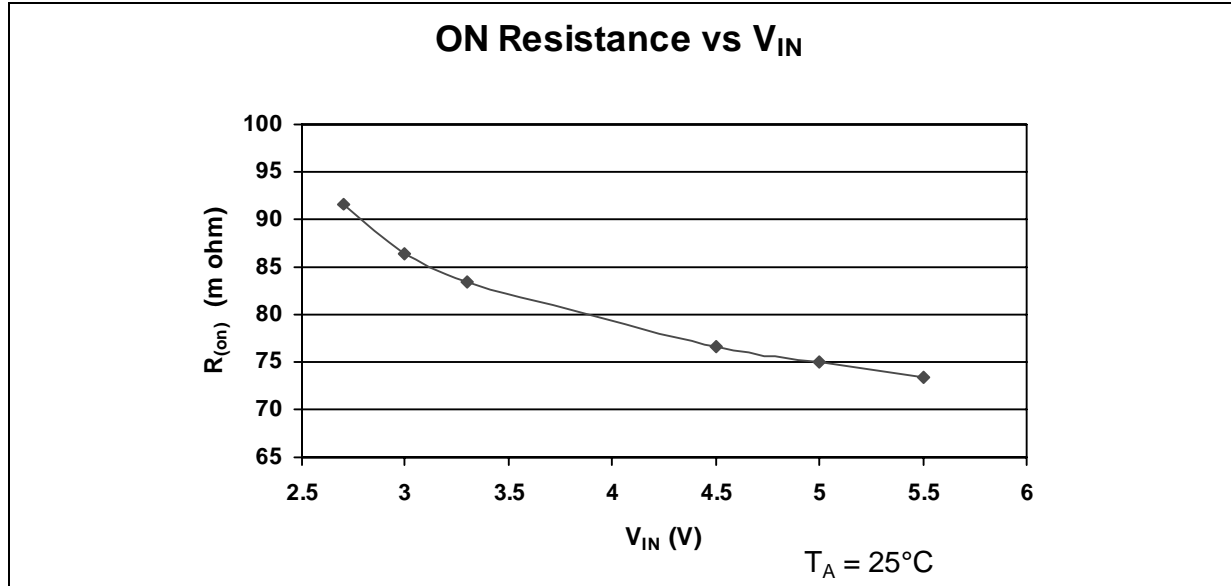


Figure 2.1 shows the  $R_{ON}$  versus the  $V_{IN}$  supply voltage. The  $R_{ON}$  depends on the  $V_{IN}$  because the P-Channel MOS is driven by the  $V_{out}$  of the internal error amplifier.

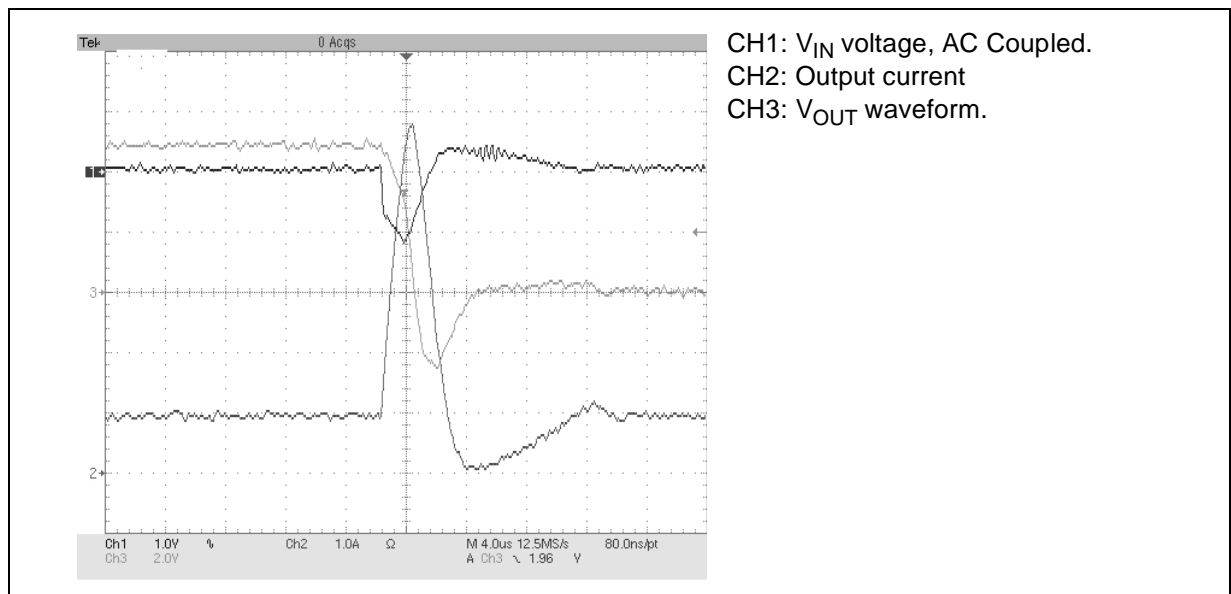
Figure 2.1: ON Resistance Versus  $V_{IN}$  Supply Voltage



### 2.2. Short Circuit Protection.

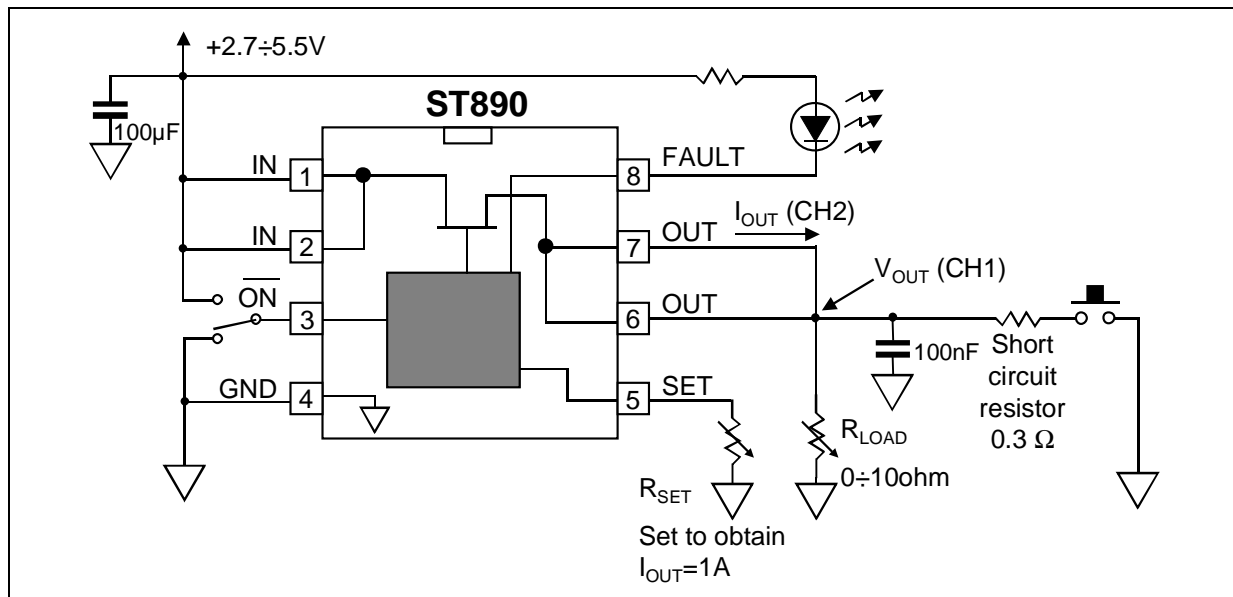
The low resistance of the MOS channel is important; however, the control circuitry that must quickly drive the MOS, in order to provide enough voltage  $V_{GS}$  to turn on the MOS channel, is more important. If the control circuitry does not drive the MOS quick enough, the current of the card could be broken, as shown in figure 2.2.

Figure 2.2: 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 (1.24V), and the error amplifier provides the  $V_{GS}$  voltage to drive the High Side P-Channel MOS. Thanks 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 1.24V (internal reference voltage). In this case the error amplifier can not 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 2.2. After the rising of the output current, the feedback circuitry begins to run and the output current is then equal or less than 1.2 times the  $I_{LIMIT}$  value. This measurement was made with the test circuit seen in figure 2.3.

Figure 2.3: Test Circuit



**Note:** To make this measurement, the Input capacitor is 100µF instead of 1µF. Typically a 1µF input capacitor, like in the demoboard circuit, is enough.

$R_{SET}$  is calculated to obtain  $I_{LIMIT}=1A$  and  $R_{LOAD}$  is set to have 1A to GND. To generate the short circuit condition the switch on the right side of figure 3b was used.

### 2.3. Programming The Current Limit.

ST890's current limit can be programmed with the SET pin. This pin is internally connected both to the current mirror, that divides the  $I_{OUT}$  by 1110, and to the error amplifier (figure 1) that realize the difference of the reference voltage and the voltage  $V_{SET}$  of the SET pin. The formula to calculate  $R_{SET}$  is:

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

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.

**2.4. Fault.**

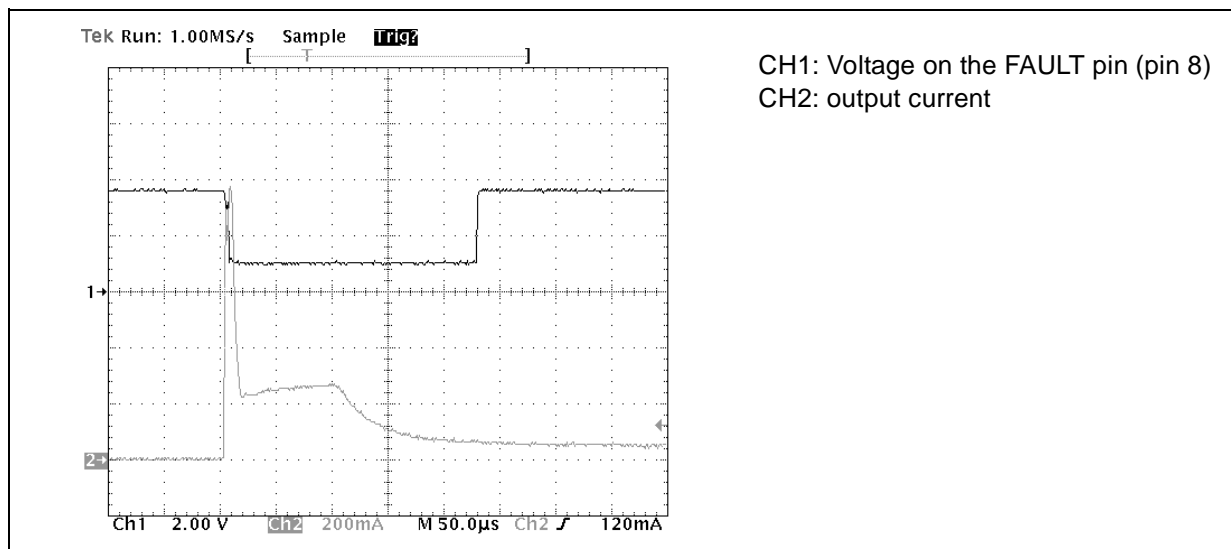
The FAULT pin (pin 8) is an Open Drain Output useful to warn the microprocessor that a fault condition has occurred. The fault condition starts in the following conditions:

- if the  $I_{OUT}$  current exceeds the  $I_{LIMIT}$  value set;
- if a short circuit occurs;
- if the devices goes in thermal protection.

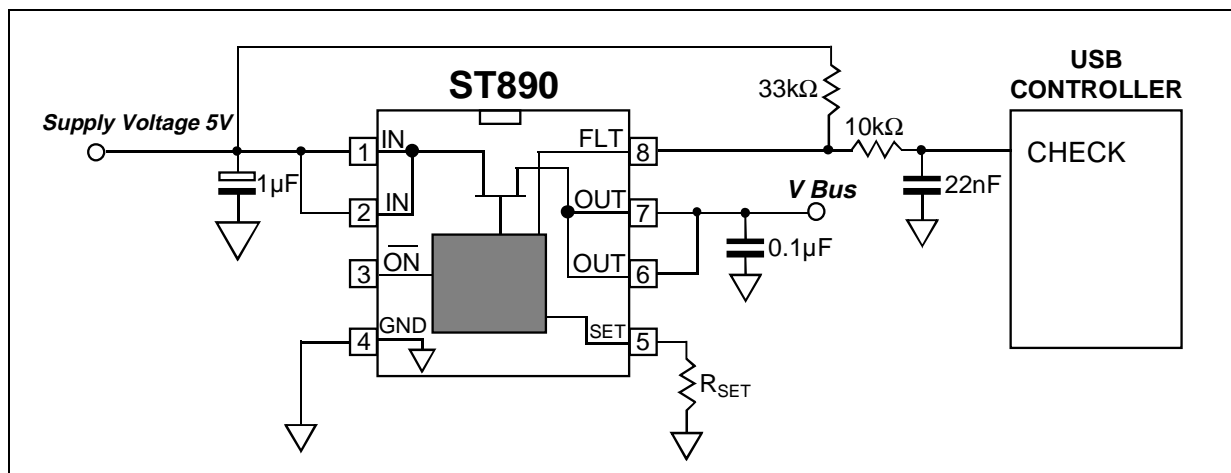
The FAULT pin should be connected to the IN pin ( $V_{CC}$ ) by a 100K pull-up resistor. This n-channel MOSFET can drive a LED in pull-up configuration as shown in figure 2.3.

In a typical USB application the ST890 typically supplies a load up to  $44\Omega$  in parallel with  $10\mu F$  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 2.4. To avoid that the controller goes in alarm, an RC filter can be placed on the FAULT pin as seen in figure 2.5.

**Figure 2.4: Fault Signal When An Inrush Condition Occurs**

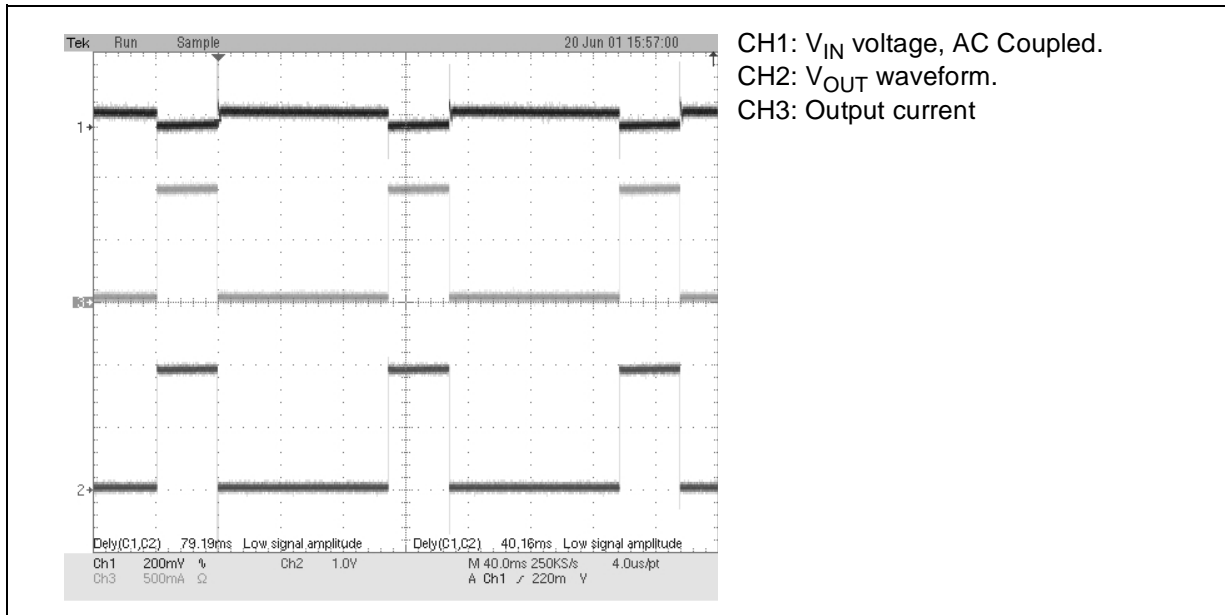


**Figure 2.5: Filter For The FAULT Transients**



2.5. Thermal Protection.

Figure 2.6: Thermal Protection Behavior



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 2.6 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.

2.6.  $\overline{ON}$  Pin Function.

Figure 2.7: Turn-on Time

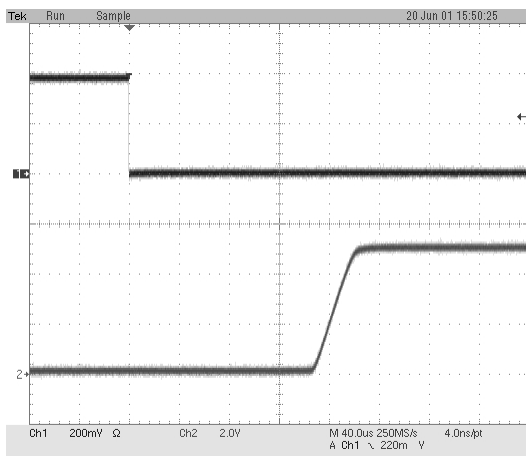
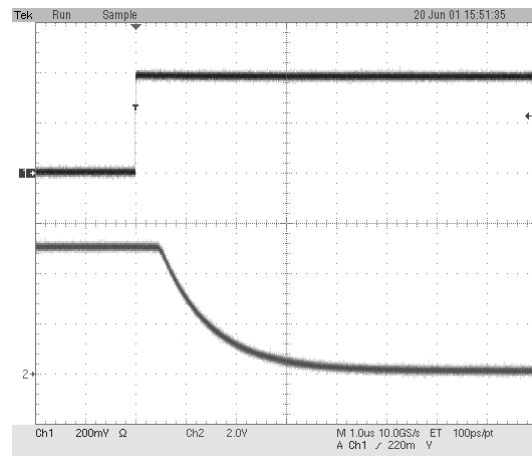


Figure 2.8: Turn-off Time



The  $\overline{ON}$  pin switches over the N-Channel MOSFET. Figures 2.7 and 2.8 respectively show the turn-on and turn-off times.

### 3. APPLICATION INFORMATION.

The ST890 application circuit needs few external components.

#### 3.1. Power Supply Filtering.

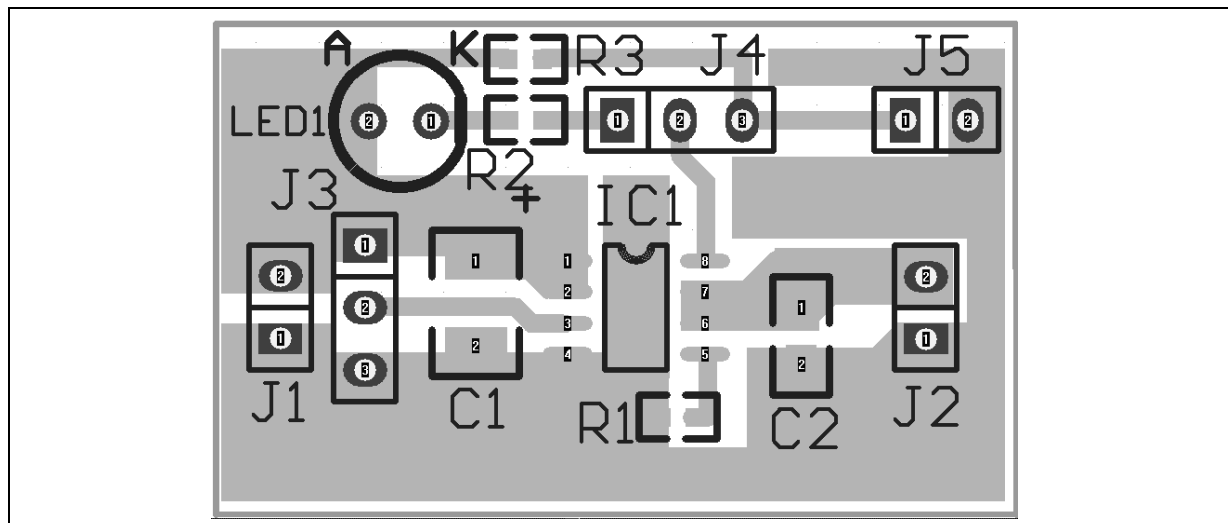
At the input a 1µF capacitor to GND can be placed in order to reduce the drop voltage during the switching and short circuit events. On the OUT pin to GND a 100nF capacitor filters the output signal. For example, figures 2.7 and 2.8 show the output voltage in a switching condition, with a load sinked current of 500mA. In order to improve the ST890 performance, the filter capacitors should be placed near the pins.

#### 3.2. PCB Rules.

Regarding the 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 ON pins are not critical.

#### 3.3. PCB Thermal Dissipation.

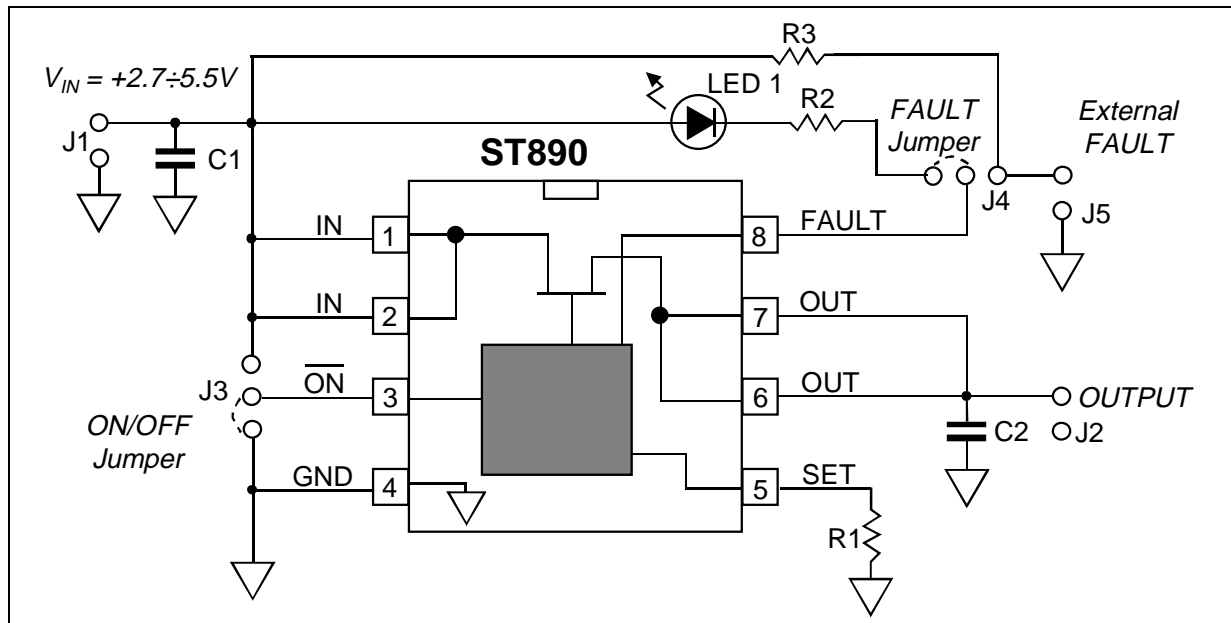
Figure 3.1: ST890 Demoboard (not to scale)



A ground plane is useful when improving the power dissipation of the ST890 device. In normal conditions the package used for the ST890 device, SO-8, can dissipate the power produced by the  $I_{LIMIT}$  current that flows in the switch,  $P = I_{LIMIT}^2 \times R_{ON}$ . This power is also equivalent to  $P = V_{SW}^2 / R_{ON}$ , 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, that continually increases until the thermal protection occurs, can be dissipated with a ground plain, as shown in figure 3.1. Figure 3.1 and 3.2 display the demoboard PCB and schematic circuit. It was designed for SMD components.

### 3.4. Demoboard Description.

Figure 3.2: ST890 Demoboard Schematic Circuit ( $I_{LIMIT}=500mA$ )



On the left side of the board the power Input connector is found, while the Output connector is found on the right side. A 3 pin connector J3 is found on the left side as well. This connector uses a “jumper” that jumps from either GND or  $V_{IN}$  to turn the switch either 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 $\Omega$  1/4W (to set  $I_{LIMIT}=500mA$ )

R2=680 $\Omega$  1/4W

R3=100K $\Omega$  1/4W

C1= 1 $\mu$ F

C2= 0.1 $\mu$ F.

IC1=ST890

LED1= 3mm LED

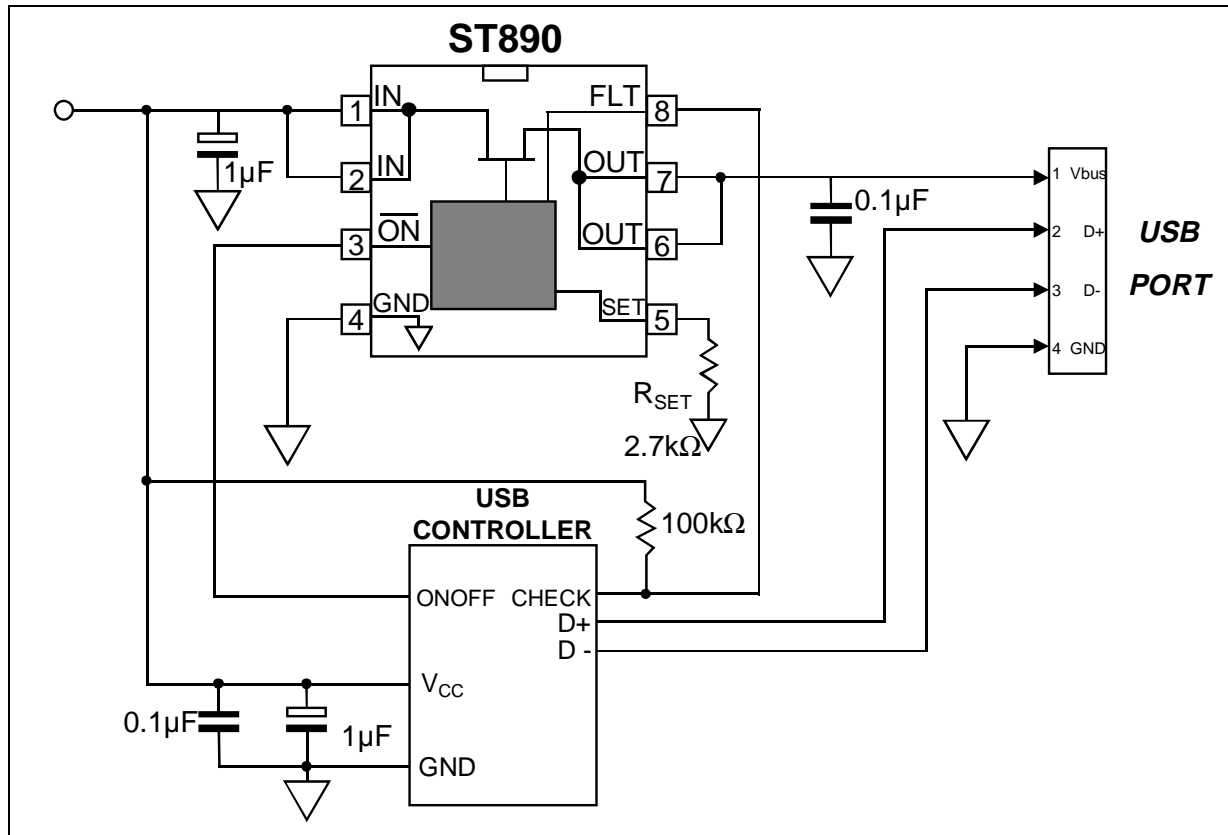
J1÷J5= straight pin Headers

### 3.5. ST890 and USB Bus.

An example of ST890’s application is the supply of the USB bus, as seen in figure 3.3.

Few components are required in ST890;  $R_{SET}$  is 2.7k $\Omega$  in order to obtain an  $I_{LIMIT}$  of 500mA and the filtering capacitance are 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-); it could even be the microcontroller ST7263.

Figure 3.3: ST890 USB Application



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