A 3.3V, 5A/10A Electronic Circuit Breaker with Thermal Protection

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Introduction

Silego's SLG4T4788 GreenPAK3 Configurable Mixed Signal IC (CMIC) is configured as a state machine for a 3.3V/5A or 3.3V/10A Electronic Circuit Breaker. It is paired with a SLG6M6201V 3.3V/10A CurrentPAK power switch. Using these two ICs, this Electronic Circuit Breaker reference design occupies less than 9mm^2 PCB area and consumes very little supply current in shutdown.

A 3.3V, 5A/10A Electronic Circuit Breaker with Thermal Protection Design and Analysis

Figure 2 is an example of implementing a 3.3V, 5A/10A Electronic Circuit Breaker with Thermal Protection. The SLG4T4788 is a Fault-current Auto-restart and Over-temperature Fault state machine designed to operate in tandem with the SLG6M6201V 3.8mΩ/10A CurrentPAK Power Switch. The SLG4T4788 is a member of Silego's industry leading GreenPAK3 family of Configurable Mixed-Signal ICs, or CMICs.

The combination of these two ICs comprises a flexible, high-performance Electronic Circuit Breaker (ECB) that can be programmed for 5A or 10A applications powered from a 3.3V rail.

The state machine designed into the SLG4T4788 can be configured to either:

a) manually restart SLG6M6201V operation after an overcurrent (OC) fault or :

b) automatically restart SLG6M6201V operation after a OC fault.

In manual mode, processor intervention is required to reset the ECB upon each detected OC fault. In auto-restart mode, the state machine will make 3 attempts to restart SLG6M6201V operation in 1-sec intervals. In either operating mode, the INT# open-drain output will be asserted when an OC-fault condition is detected (or the automatic 3-cycle load restart loop elapses).

Manual Restart Mode: If the RESTART pin is LOW, the SLG4T4788 will turn off the SLG6M6201V and assert INT# upon a detected OC fault. The SLG4T4788 will keep the SLG6M6201V OFF until the processor toggles the SLG4T4788's ENABLE signal LOW-to-HIGH to reset the ECB.

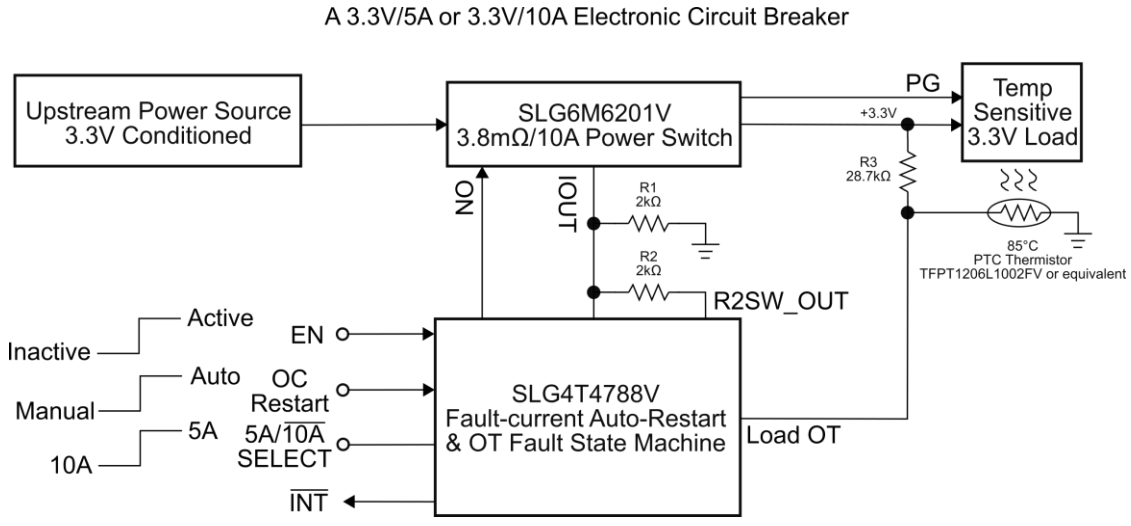


Figure 1. Typical application circuit

Auto-Restart Mode: If the RESTART pin is HIGH, the SLG4T4788 will initially turn off the SLG6M6201V upon a detected load-OC fault. The state machine will first begin a 3-cycle auto restart loop where the SLG6M6201V will be turned on and immediately turn off if OC remains in each of the (3) 1-second cycles until the fault current condition has either elapsed or has been removed. Once the OC condition no longer exists or before the 3-cycle loop elapses, the SLG6M6201V resumes nominal operation. In the event that, after (3) attempts to restart the SLG6M6201V prove unsuccessful, the state machine will turn off the SLG6M6201V and assert INT#. Processor intervention would then be required to toggle the state machine's ENABLE input LOW-to-HIGH to reset the ECB.

Over-temperature (OT) Protection: Using an external PTC thermistor remotely located at the load, over-temperature protection is also available. When the load temperature sensed by the PTC thermistor exceeds 85°C, the state machine will turn off the SLG6M6201V and assert INT#. To reset the ECB requires the processor to toggle the state machine's ENABLE input LOW-to-HIGH. So long as the LOAD_OT signal indicates that the load circuit's temperature is less than 85°C, nominal ECB operation is re-enabled. In this design, a TFPT1206L1002FV PTC thermistor was used with a 28.7kΩ pull-up resistor as the load circuit's OT trigger to the SLG4T4788.

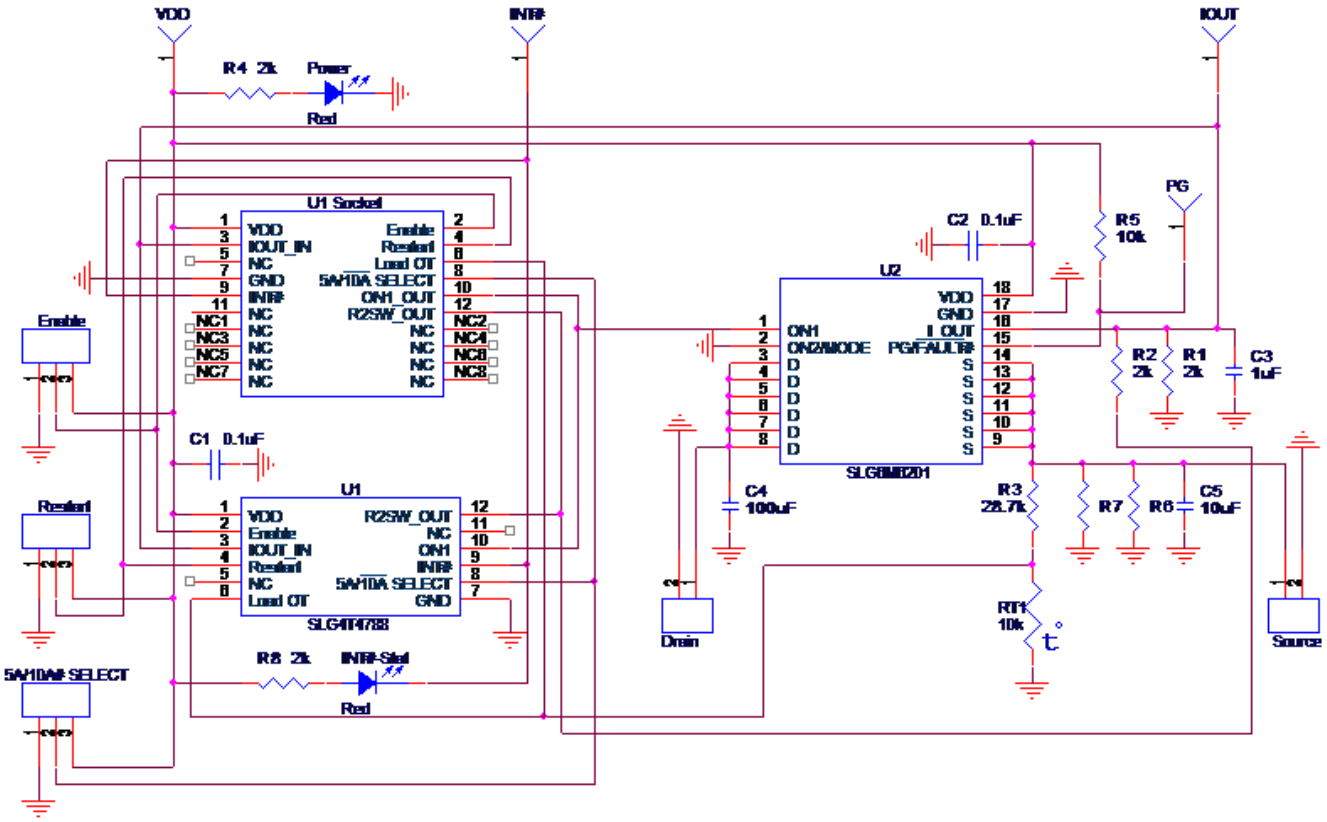


Figure 2. A 3.3V, 5A/10A Electronic Circuit Breaker with Thermal Protection

User-selectable 5A or 10A ECB Operation: The SLG4T4788 state machine includes the ability for the system to select a 5A or a 10A OC detection. If the 5A/10A# SELECT pin is HIGH, the load resistor connected to the SLG6M6201V's load-current sense output pin at IOUT is 2kΩ (R1). In this configuration, the SLG6M6201V OC detection is set for 5A. If the 5A/10A# SELECT pin is LOW, the load resistor connected to the SLG6M6201V's IOUT pin is switched to 1kΩ by the state-machine's open-drain at R2SW_OUT. The SLG6M6201V's OC detection is then set for 10A.

Adjusting the SLG6M6201V OC Detection Thresholds: To adjust the OC detection levels to other than 5A (OCL) or 10A (OCH) is a matter of adjusting R1 and R2.

When OCL/OCH# SELECT pin polarity is HIGH, the low OC detection setting for the SLG6M6201V is selected. In this case, R1 is the load resistance at the SLG6M6201V's IOUT pin and is determined according to the following equation:

$$R1\ (k\Omega) = \frac{10}{IOCL(A)}$$

where IOCL(A) = OC (low) detection current setting for the SLG6M6201V expressed in amps (A).

Similarly, when OCL/OCH# SELECT pin polarity is LOW, the SLG6M6201V is configured for high OC detection and the effective load resistance at the SLG6M6201V's IOUT pin is the parallel combination of R1 and R2. Therefore, the value for R2 can be calculated according to the following equation:

$$R2\ (k\Omega) = \frac{10}{IOCH(A)-IOCL(A)}$$

where IOCH (A) = OC (high) detection current setting for the SLG6M6201V expressed in amps (A). In the circuit presented here, IOCL and IOCH were selected at 5A and 10A, respectively.

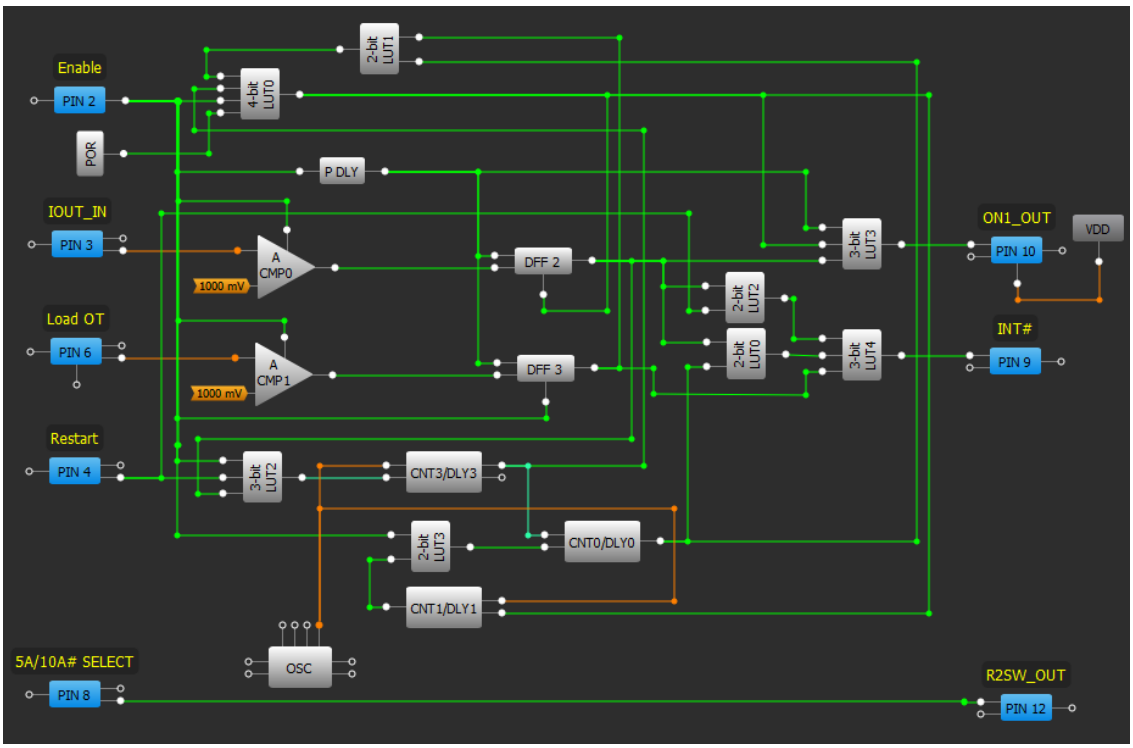


Figure 3. SLG4T4788 Design for 3.3V, 5A/10A Electronic Circuit Breaker with Thermal Protection

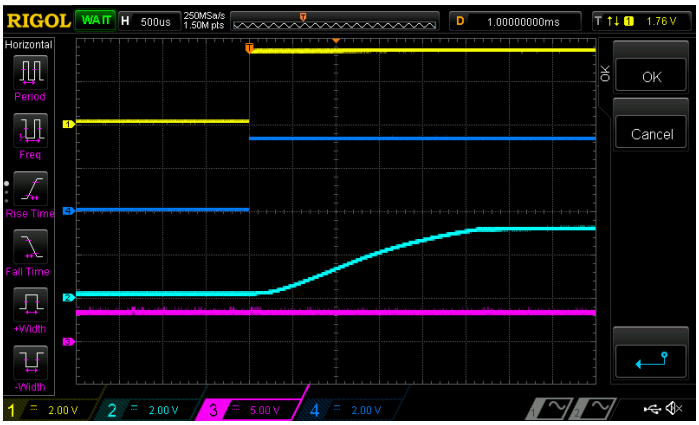
In this example, both R1 and R2 were calculated to be 2kΩ. If, for example, IOCL and IOCH were selected at 4A and 7.5A, respectively, then R1 would be equal to 2.5kΩ (2.49kΩ is the closest E96 1% tolerance value) for the low IOCL setting at 4A. For the IOCH setting, R2 would be equal to 2.86kΩ (2.87kΩ is the closest E96 1% tolerance value). Thus, when OCL/OCH# SELECT pin polarity is LOW, the parallel combination of R1 and R2 would be 1.33kΩ, and the OC detection threshold for the ECB would be 7.5A.

ECB's Fault Detection Times: Typical SLG6M6201 turn-off response times (HIGH-to-LOW transitions on ON1_OUT) range from 16.2µs to 21µs because of normal part-to-part variation in production.

Typical SLG4T4788 internal ACMP0 and ACMP1 comparator response times are a function of the transition speeds of the signals applied to their inputs. For fast-moving trigger signals, ACMP0 (SLG4T4788 Pin3) and ACMP1 (SLG4T4788 Pin 6) response times can be as fast as 1µs; for slow-moving trigger signals, the response times can be as long as 6µs. Therefore, the ECB's total detection response times to over-current and/or over-temperature faults can range from 17.2µs to 27µs.

Functional Waveforms

1. ECB Power-up Sequence
2. ECB Power-down Sequence

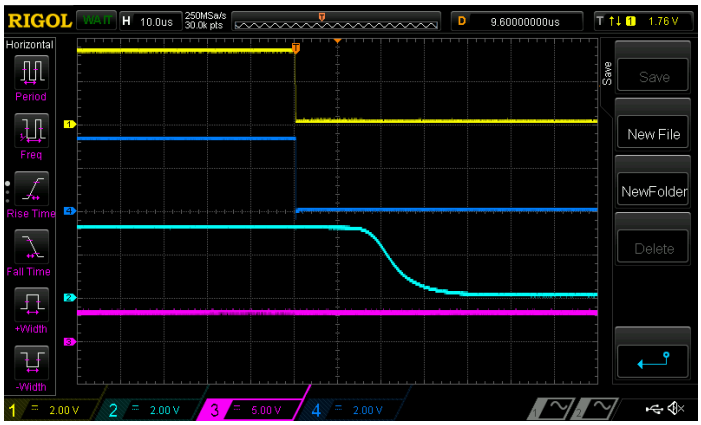


Channel 1 (yellow) – PIN2 Enable signal

Channel 2 (light blue) – Source pin on the SLG6M6201 side

Channel 3 (pink) – PIN9 INT# signal

Channel4 (dark blue) – PIN10 ON1_OUT signal



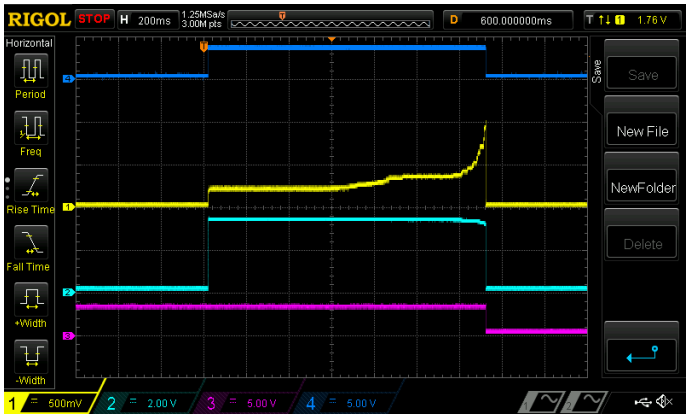
Channel 1 (yellow) – PIN2 Enable signal

Channel 2 (light blue) – Source pin on the SLG6M6201 side

Channel 3 (pink) – PIN9 INT# signal

Channel4 (dark blue) – PIN10 ON1_OUT signal

3. ECB OC Detection/Shutdown Operation – Manual Mode



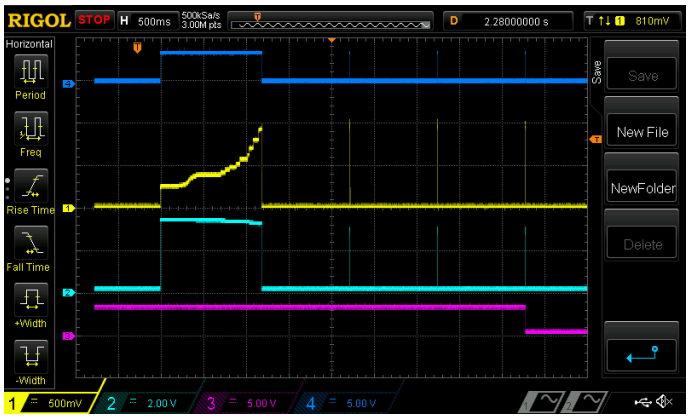
Channel 1 (yellow) – PIN3 IOUT_IN signal

Channel 2 (light blue) – Source pin on the SLG6M6201 side

Channel 3 (pink) – PIN9 INT# signal

Channel4 (dark blue) – PIN10 ON1_OUT signal

4. a) ECB OC Detection/Shutdown Operation – Auto Restart



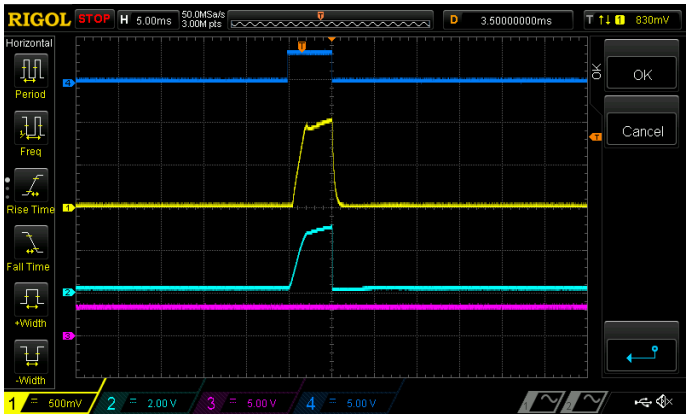
Channel 1 (yellow) – PIN3 IOUT_IN signal

Channel 2 (light blue) – Source pin on the SLG6M6201 side

Channel 3 (pink) – PIN9 INT# signal

Channel4 (dark blue) – PIN10 ON1_OUT signal

4. b) Magnified Single-cycle Auto Restart Details



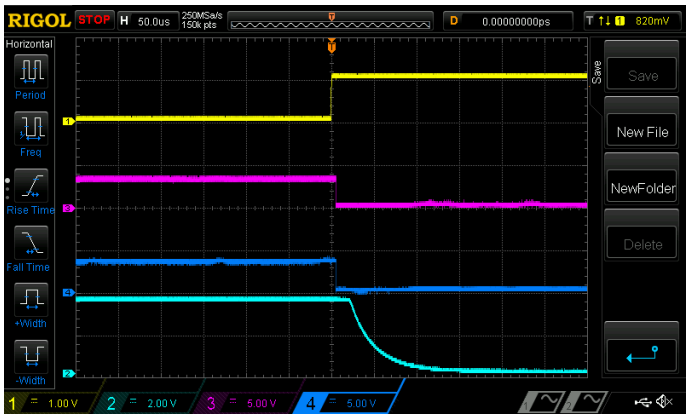
Channel 1 (yellow) – PIN3 IOUT_IN signal

Channel 2 (light blue) – Source pin on the SLG6M6201 side

Channel 3 (pink) – PIN9 INT# signal

Channel4 (dark blue) – PIN10 ON1_OUT signal

5. ECB OT Detection/Shutdown Operation



Channel 1 (yellow) – PIN6 Load OT signal

Channel 2 (light blue) – Source pin on the SLG6M6201 side

Channel 3 (pink) – PIN9 INT# signal

Channel4 (dark blue) – PIN10 ON1_OUT signal

PCB Layout and Suggestions

If SLG6M6201 will be used for high current, it is highly recommend to use 2oz copper thickness.

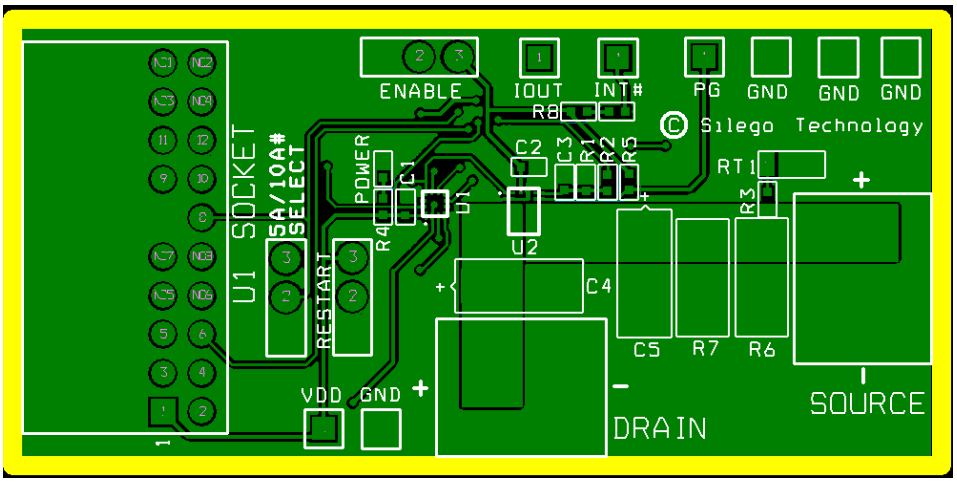


Figure 4. Top View of the Demo Board

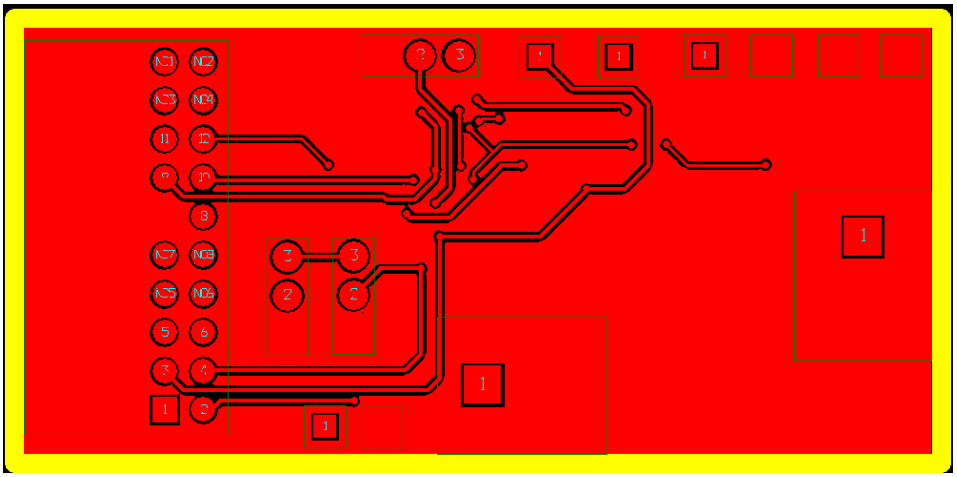


Figure 5. Bottom View of the Demo Board

During PCB Layout it is highly recommended to put C3, R1, R2 components close to pin16 of the SLG6M6201. Also, the trace from R1, R2 to pin3 of the SLG4T4788 should be as short as possible.

To provide good voltage transfer from IOUT of SLG6M6201 to pin3 of SLG4T4788, it is recommended that GND between U1, U2, C3 and R1, R2 have minimized perforations and inductance to avoid GND bounce and GND loops.

Bill of Materials

No	Item	Quantity	Comment	Symbol
1	SLG6M6201	1	Silego	U2
2	SLG4T4788	1	Silego	U1
3	CL05F104ZO5NNNC	2	CAP CER 0.1UF 16V Y5V 0402	C1, C2
4	C1005X5R1C105K050BC	1	CAP CER 1UF 16V 10% X5R 0402	C3
5	68000-203HLF	3	BERGSTIK II .100" SR STRAIGHT	Enable, Restart, 5A/10A# SELECT
6	4-881545-2	3	SHUNT LP W HANDLE 2 POS SN	Jumper for Enable, Restart, 5A/10A# SELECT
7	LNJ247W82RA	2	LED RED RECTANGLE SMD	Power, INT#
8	282856-2	2	TERM BLOCK 2POS SIDE ENTRY 5MM	Drain, Source
9	ERJ-2GEJ202X	2	RES 2.0K OHM 1/10W 5% 0402 SMD	R4, R8
10	ERA-2AEB202X	2	RES SMD 2K OHM 0.1% 1/16W 0402	R1, R2
11	ERJ-2GEJ103X	1	RES 10K OHM 1/10W 5% 0402 SMD	R5
12	ERJ-2RKF2872X	1	RES SMD 28.7K OHM 1% 1/10W 0402	R3
13	TFPT1206L1002FV	1	THERMISTOR PTC 10K OHM 1% 1206	RT1
14	87224-1	2	CONN HEADER VERT .100 1POS 15AU	VDD, GND
15	PPTC102LJBN-RC	1	CONN FEMALE 20POS DL .1" R/A TIN	U1 Socket

Table 1. Bill of Materials

Conclusion

Using Silego's SLG4T4788 and SLG6M6201 it is easy to create a low cost and reliable system for over current and overtemperature protection. Having switching between 5A or 10A overcurrent protection makes this design very flexible to control current in different device operation modes. This solution can be very useful in servers, notebooks, tablets, smartphones, where overcurrent or overtemperature features offer protection for those devices.

Related Files

1. Programming Code for GreenPAK Designer
2. Gerber Files for Evaluation Board
3. BOM file for ordering components directly from DigiKey
4. SLG6M6201 datasheet

http://www.silego.com/products/currentpak.html

5. SLG4T4788 datasheet

About the Author

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A	Petro Zeykan	06/04/2015	New application note

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