SLG4T4788

GreenPAK™

SLG6M6201V Electronic Circuit Breaker State Machine

General Description

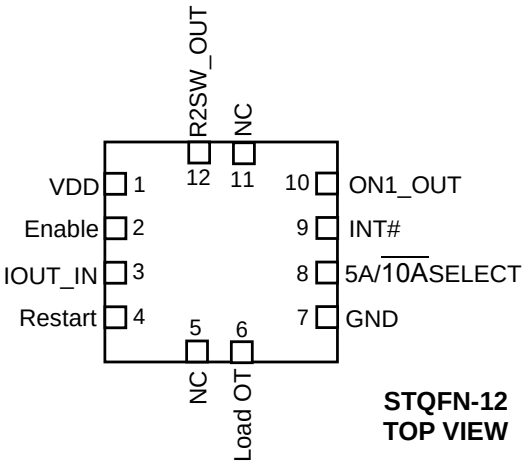
The Silego SLG4T4788 is GreenPAK3 Configurable Mixed Signal IC (CMIC) configured as a state machine for a 3.3V/5A or 3.3V/10A Electronic Circuit Breaker when paired with a SLG6M6201V 3.3V/10A CurrentPAK power switch. Using two ICs, this Electronic Circuit Breaker reference design occupies less than 9mm^2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

For complete information on the SLG6M6201V, please consult the SLG6M6201 product datasheet.

A reference design kit for this SLG6M6201/SLG4T4788V-based electronic circuit breaker is available from Silego and it includes a BOM and pcb layout. Please refer to document RD-0001 for additional information.

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

Pin Configuration

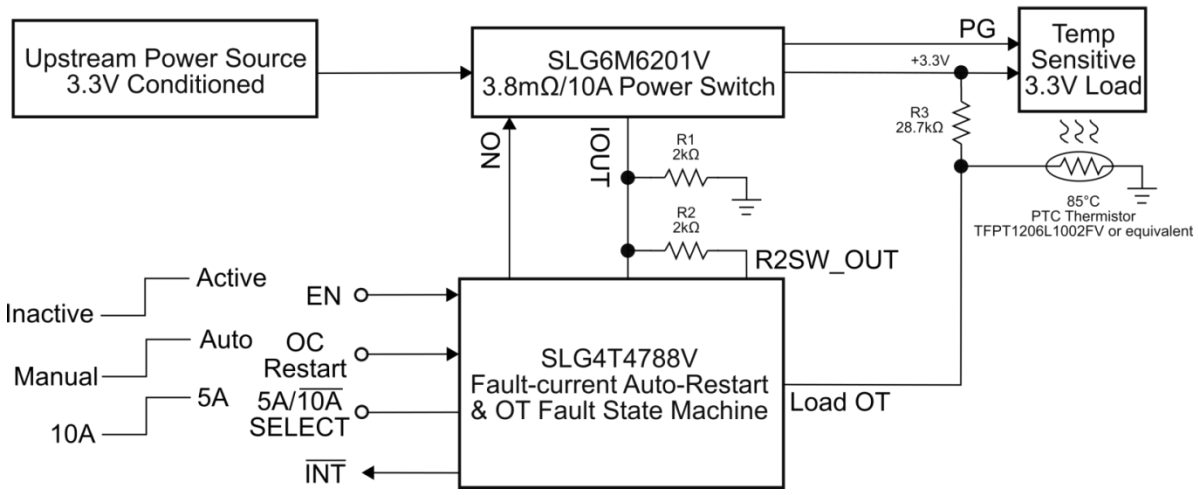


STQFN-12
TOP VIEW

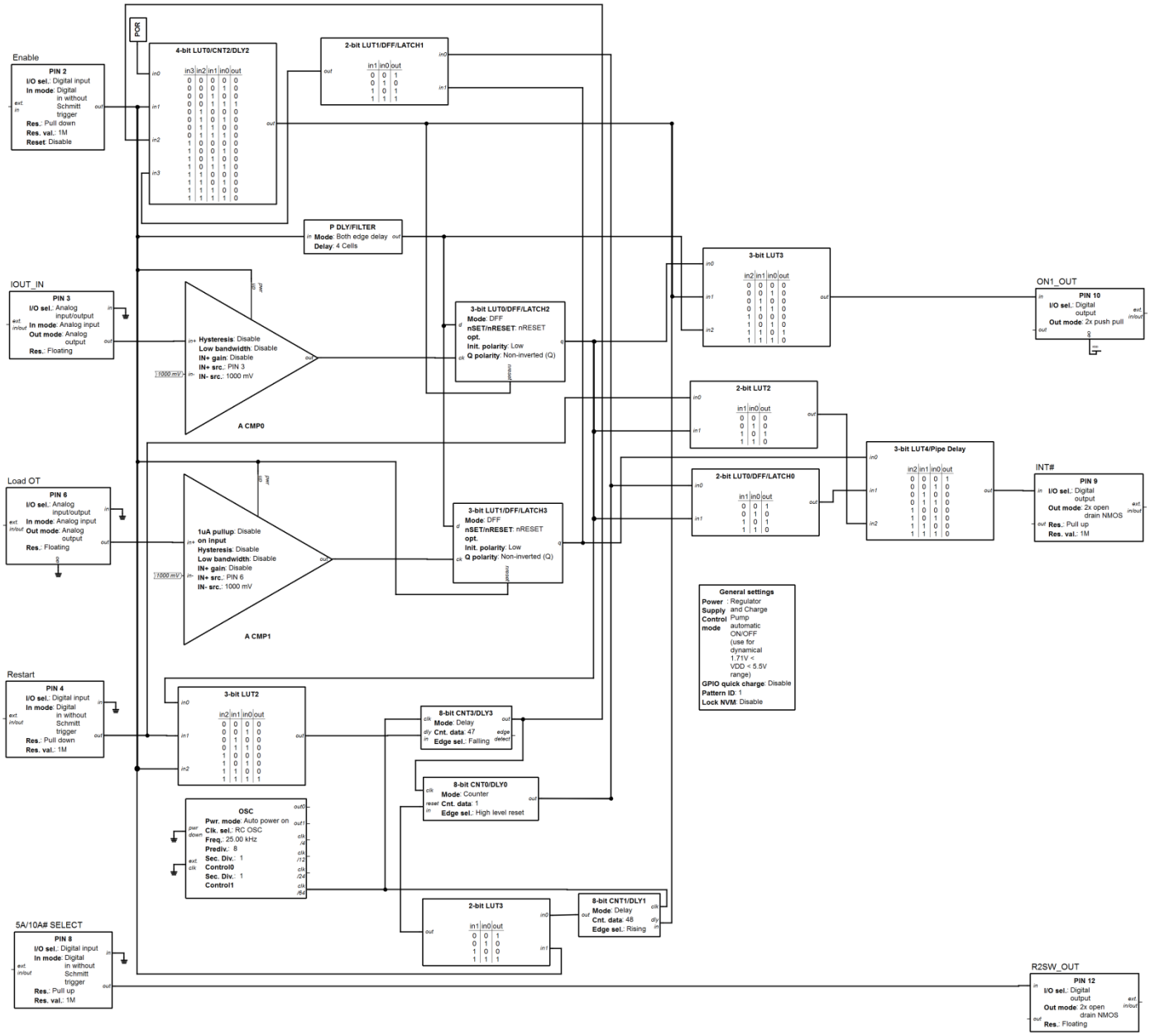
Features

- Manual or Auto-restart on Fault Current
- Programmable Over-temperature Fault Detection
- User selectable 5A or 10A Circuit Breaker Operation
- Programmable Fault Detection Response Times
- Low Power Consumption
- Very Low Supply Current in Shutdown
- Pb-Free, RoHS Compliant, and Halogen-Free Packaging

A 3.3V/5A or 3.3V/10A Electronic Circuit Breaker



Block Diagram of the SLG4T4788 Electronic Circuit Breaker State Machine



Pin Configuration

Pin #	Pin Name	Type	Pin Description
1	VDD	PWR	Power Supply Voltage connection to the SLG4T4788. Apply a regulated/conditioned 3.3V power source to this pin bypassed to GND with a 0.1µF ceramic capacitor
2	Enable	Digital Input	An active-HIGH asserted digital input, a low-to-high transition on ENABLE turns on the Electronic Circuit Breaker (ECB). Upon fault detection, toggling ENABLE high-to-low-to high resets the ECB.
3	IOUT_IN	Analog Input/Output	An analog input pin, IOUT_IN is connected directly to the SLG6M6201V's IOUT pin.
4	Restart	Digital Input	An active-HIGH asserted digital input, a LOW on this pin configures the ECB to manual mode upon fault detection. When RESTART is HIGH, the ECB will attempt to restart ECB operation OC operation automatically.
5	NC	--	No connection or connect to GND
6	Load OT	Analog Input/Output	An analog input pin, Load_OT is the load circuit's OT sensor connection to an external PTC thermistor.
7	GND	GND	Ground. This pin should be connected to the same ground plane as that of the SLG6M6201V.
8	5A/$\overline{10A}$ SELECT	Digital Input	An active-HIGH asserted digital input, a LOW state configures the ECB for its high OC detection setting. A HIGH state configures the ECB to its low OC detection setting.
9	INT#	Digital Output	An active-LOW open-drain digital output, INT# is asserted upon the detection of a OC fault in manual mode, after 3-cycle timeout in auto-restart mode, or upon a OT fault in either mode.
10	ON1_OUT	Digital Output	An active-HIGH push-pull output, ON1_OUT is SLG6M6201V's ON control signal that starts the power switch's operation.
11	NC	--	No connection or connect to GND
12	R2SW_OUT	Digital Output	An active-LOW open-drain digital output, R2SWOUT is the drain connection of a n-channel pull-down transistor used to connect R2 to GND when enabled. A HIGH state on this pin configures the state machine to its low OC detection setting. A LOW state on this pin configures the state machine to its high OC detection setting.

Ordering Information

Part Number	Package Type
SLG4T4788V	V=STQFN-12
SLG4T4788VTR	STQFN-12 – Tape and Reel (3k units)

Absolute Maximum Conditions

Parameter	Min.	Max.	Unit
V_{HIGH} to GND	-0.3	7	V
Voltage at input pins	-0.3	7	V
Current at input pin	-1.0	1.0	mA
Storage temperature range	-65	125	°C
Junction temperature	--	150	°C
ESD Protection (Human Body Model)	2000	--	V
ESD Protection (Charged Device Model)	1000	--	V
Moisture Sensitivity Level	1		

Electrical Characteristics

(@ 25°C, unless otherwise stated)

Symbol	Parameter	Condition/Note	Min.	Typ.	Max.	Unit
V_{DD}	Supply Voltage		3	3.3	3.6	V
T_A	Operating Temperature		-40	25	85	°C
I_Q	Quiescent Current	Static inputs and outputs	--	65	--	µA
V_O	Maximal Voltage Applied to any PIN in High-Impedance State		--	--	VDD	V
I_O	Maximal Average or DC Current (note 1)	Per Each Chip Side	--	--	90	mA
V_{IH}	HIGH-Level Input Voltage	Logic Input, at VDD=3.3V	1.78	--	VDD	V
V_{IL}	LOW-Level Input Voltage	Logic Input, at VDD=3.3V	--	--	1.21	V
I_{IH}	HIGH-Level Input Current	Logic Input PINs; V_{IN} = VDD	-1.0	--	1.0	µA
I_{IL}	LOW-Level Input Current	Logic Input PINs; V_{IN} = 0V	-1.0	--	1.0	µA
V_{OH}	HIGH-Level Output Voltage (note 1)	Push Pull & PMOS OD, I_{OH} = 3mA, 2X Driver, at VDD=3.3 V	2.87	3.19	--	V
V_{OL}	LOW-Level Output Voltage (note 1)	Push Pull, I_{OL} = 3mA, 2X Driver, at VDD=3.3 V	--	0.09	0.13	V
		Open Drain, I_{OL} = 3mA, 2X Driver, at VDD=3.3 V	--	0.050	0.071	
I_{OH}	HIGH-Level Output Current (note 1)	Push Pull & PMOS OD, V_{OH} = 2.4 V, 2X Driver, at VDD=3.3 V	11.264	19.648	--	mA

I_{OL}	LOW-Level Output Current (note 1)	Push Pull, V_{OL} =0.4V, 2X Driver, at VDD=3.3 V	8.13	12.358	--	mA
		Open Drain, V_{OL} =0.4V, 2X Driver, at VDD=3.3 V	15.648	22.897	--	
V_{ACMP0}	Analog Comparator Threshold Voltage	ACMP0 threshold including input offset, reference voltage variation and hysteresis.	957	--	1038	mV
V_{ACMP1}	Analog Comparator Threshold Voltage	ACMP1 threshold including input offset, reference voltage variation and hysteresis.	957	--	1038	mV
R_{PULL_UP}	Internal Pull Up Resistance	Pull up on PINs 8, 9	700	1000	1300	kΩ
R_{PULL_DOWN}	Internal Pull Down Resistance	Pull down on PINs 2, 4	700	1000	1300	kΩ
T_{DLY1}	Delay1 Time	At temperature 25°C	997.46	1034.24	1073.8	ms
		At temperature -40°C +85°C (note 1)	897	1034.24	1267.66	
T_{DLY3}	Delay3 Time	At temperature 25°C	977.51	1013.76	1052.75	ms
		At temperature -40°C +85°C (note 1)	879.06	1013.76	1242.8	
T_{SU}	Start up Time	From VDD rising past 1.6V	--	1	--	ms

1. Guaranteed by Design.

Theory of Operation

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 highly-successful 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 $\overline{\text{INT}}$ 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 $\overline{\text{INT}}$ 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.

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 $\overline{\text{INT}}$. 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 $\overline{INT}$. 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.

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/$\overline{10A}$ 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/$\overline{10A}$ 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/$\overline{OCH}$ 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/$\overline{OCH}$ 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:

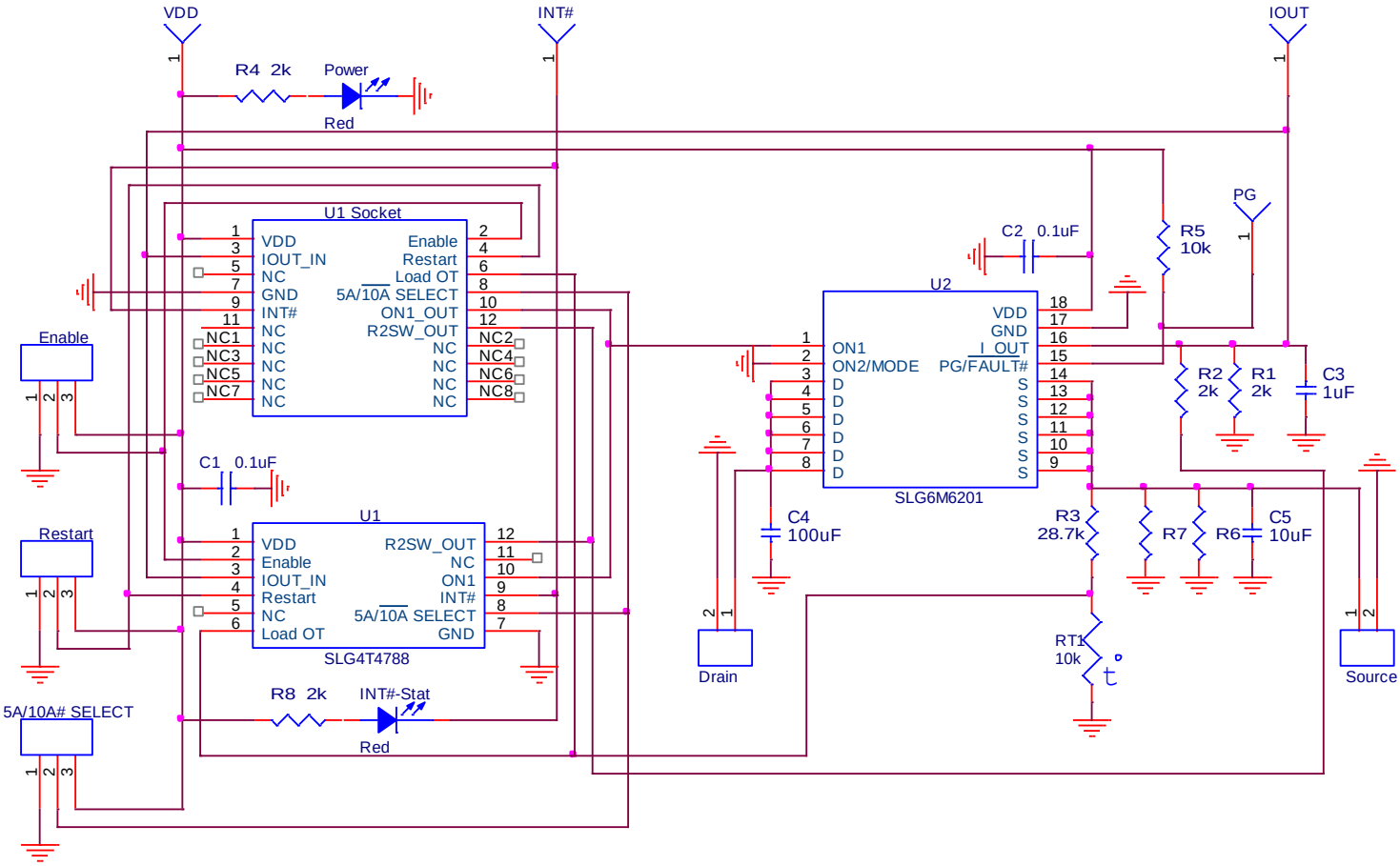
$$R2\ (k\Omega) = \frac{10}{IOCH(A)-IOCL(A)}$$

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. 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/$\overline{\text{OCH}}$ 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.

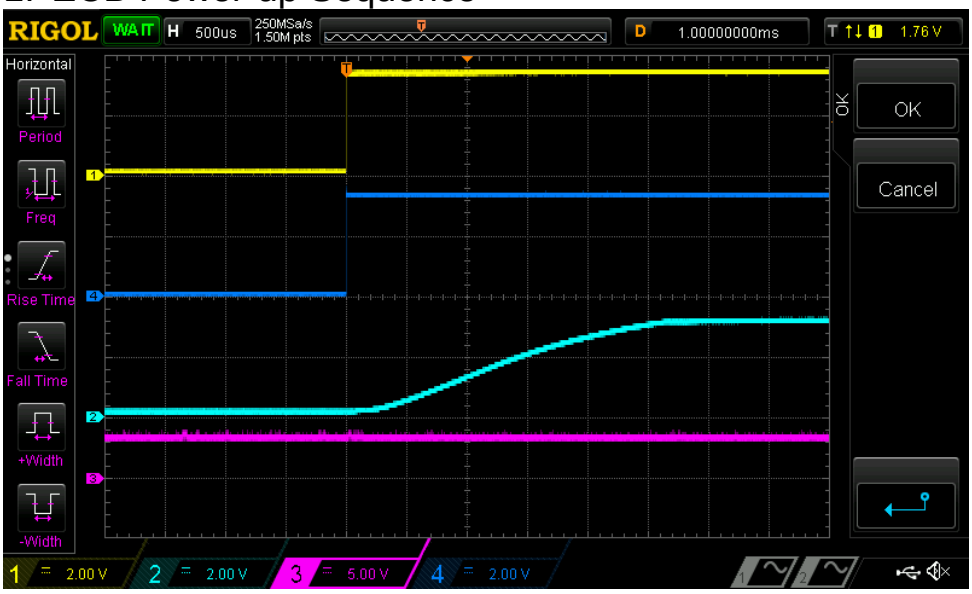
ECB's Fault Detection Times: Typical SLG6M6201 turn-off response times (HIGH-to-LOW transitions on ON1_OUT) range from 16.2µs to 21µs because of part-to-part variations in production. Typical SLG4T4788 internal ACMP0 and ACMP1 comparator response times are a function of the transition speeds of the signals 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.

Evaluation Kit Circuit Diagram



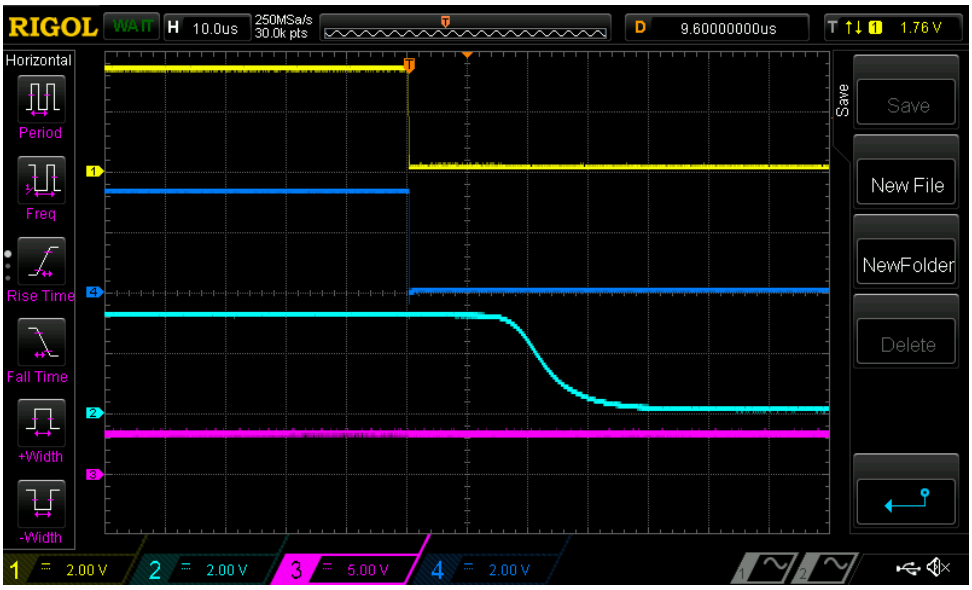
Functionality Waveforms

1. ECB Power-up Sequence



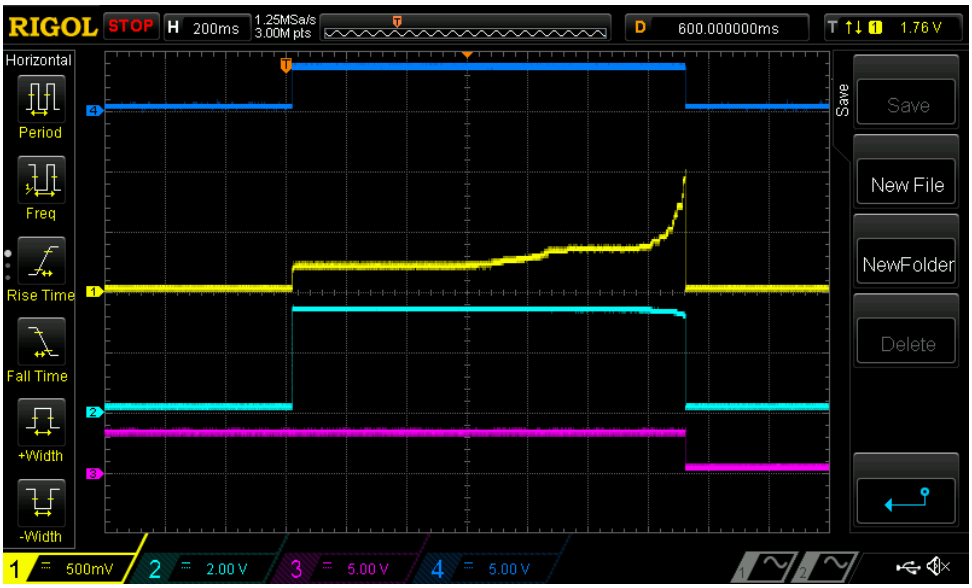
Channel 1 (yellow) – PIN2 Enable signal
Channel 2 (light blue) – Source pin on the SLG6M6201 side
Channel 3 (pink) – PIN9 INT# signal
Channel4 (dark blue) – PIN10 ON1_OUT signal

2. ECB Power-down Sequence



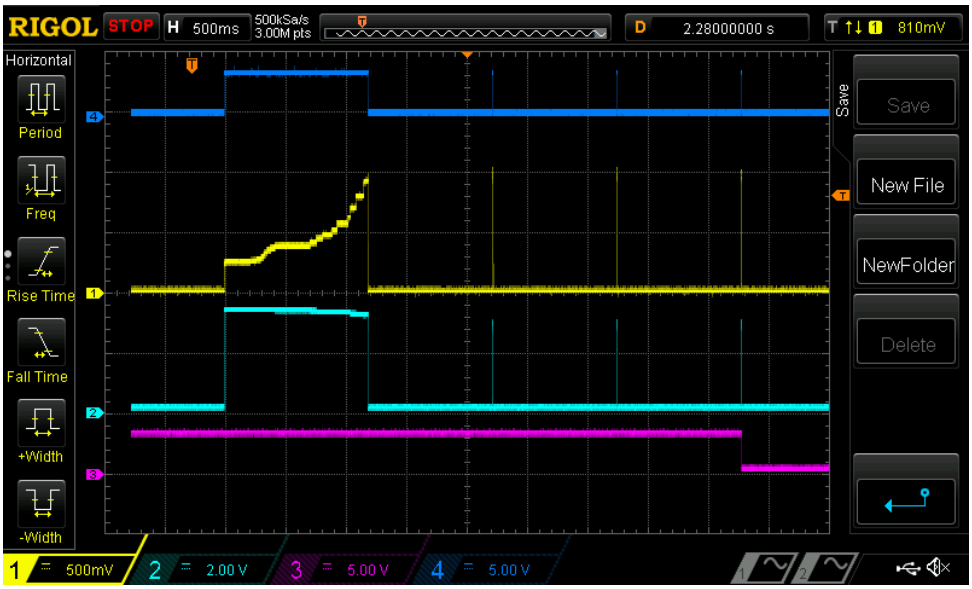
Channel 1 (yellow) – PIN2 Enable signal
Channel 2 (light blue) – Source pin on the SLG6M6201 side
Channel 3 (pink) – PIN9 INT# signal
Channel4 (dark blue) – PIN10 ON1_OUT signal

3. ECB OC Detection/Shutdown Operation – Manual Mode



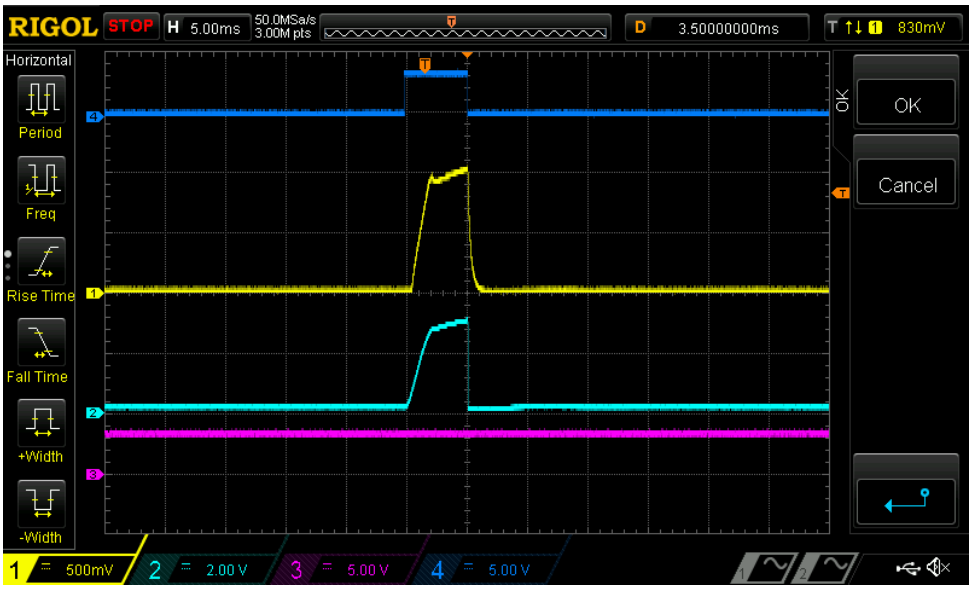
Channel 1 (yellow) – PIN3 IOUT_IN signal
Channel 2 (light blue) – Source pin on the SLG6M6201 side
Channel 3 (pink) – PIN9 INT# signal
Channel4 (dark blue) – PIN10 ON1_OUT signal

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



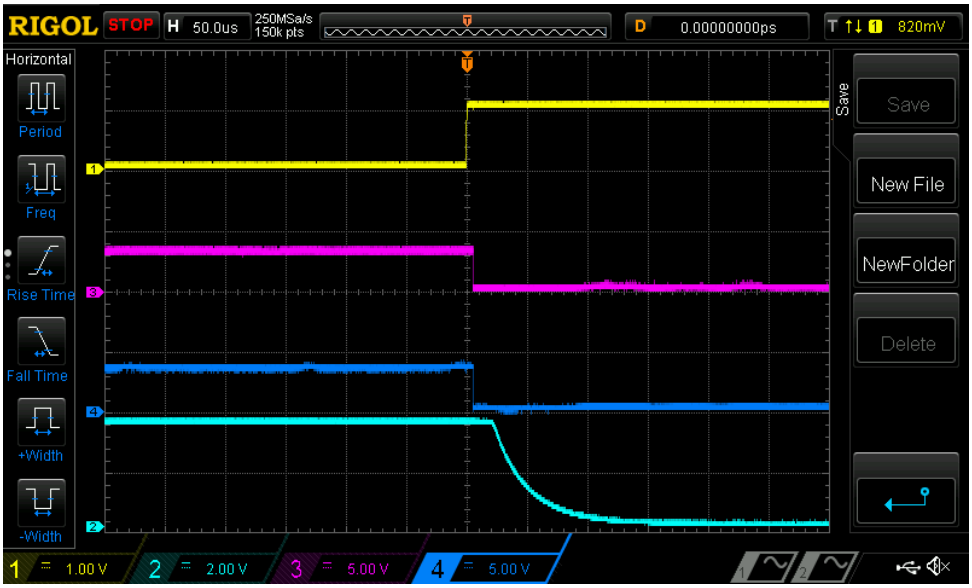
Channel 1 (yellow) – PIN3 IOUT_IN signal
Channel 2 (light blue) – Source pin on the SLG6M6201 side
Channel 3 (pink) – PIN9 INT# signal
Channel4 (dark blue) – PIN10 ON1_OUT signal

4. b) Magnified Single-cycle Auto Restart Details



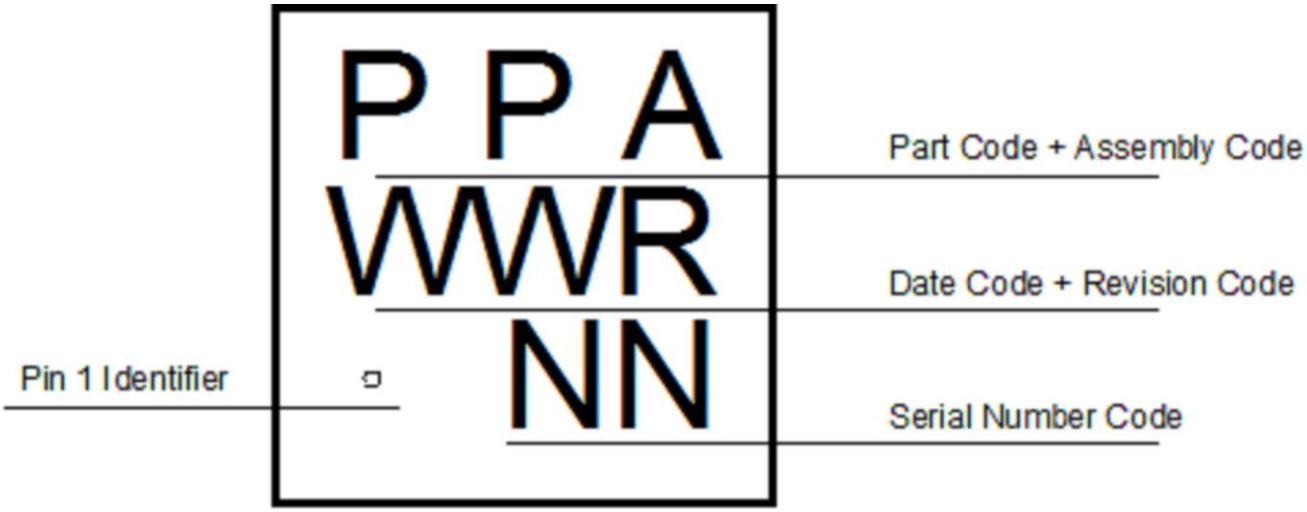
Channel 1 (yellow) – PIN3 IOUT_IN signal
Channel 2 (light blue) – Source pin on the SLG6M6201 side
Channel 3 (pink) – PIN9 INT# signal
Channel4 (dark blue) – PIN10 ON1_OUT signal

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

Package Top Marking

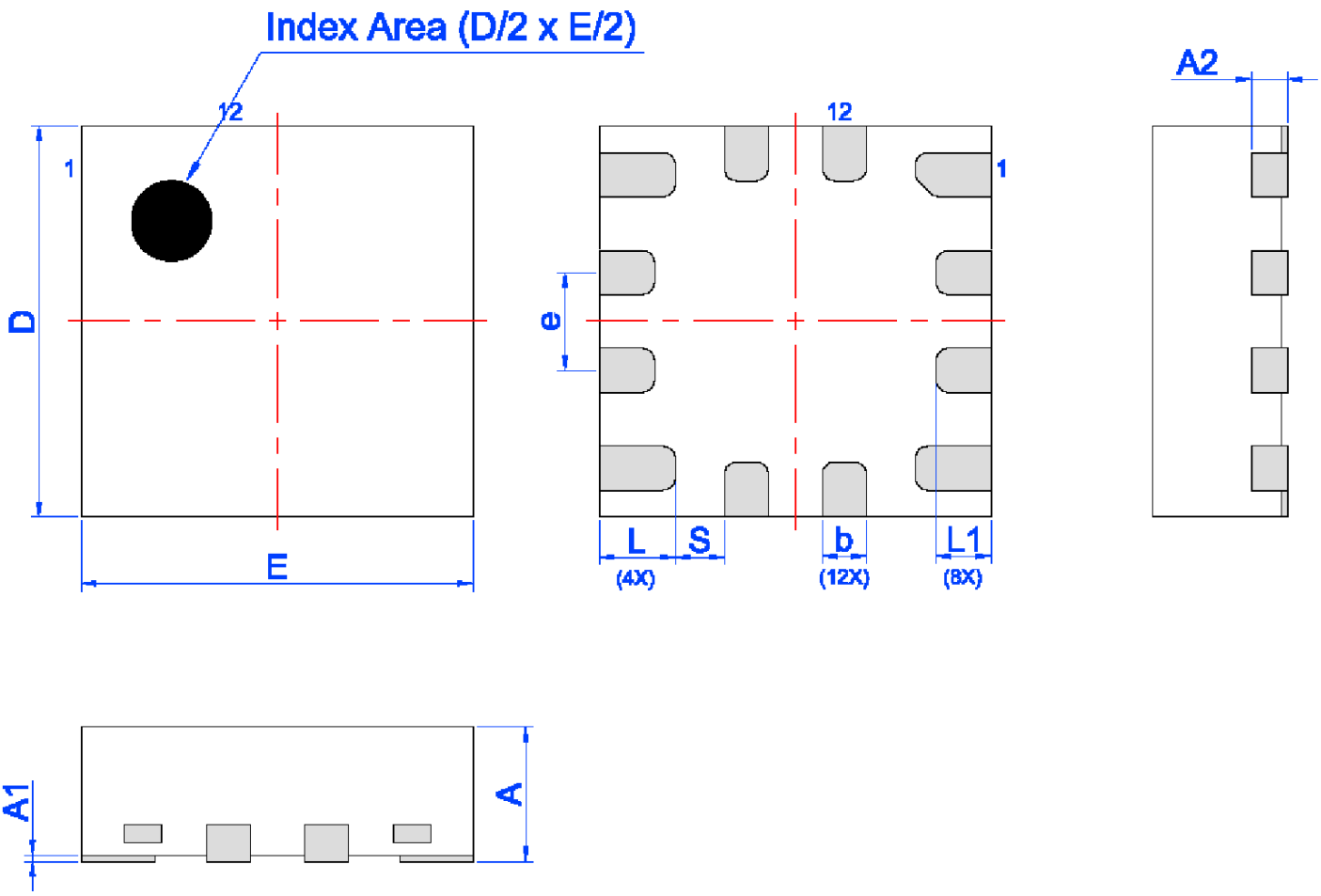


Datasheet Revision	Programming Code Number	Locked Status	Part Code	Revision	Date
0.10	001	U			06/03/2015

The IC security bit is locked/set for code security for production unless otherwise specified. Revision number is not changed for bit locking.

Package Drawing and Dimensions

12 Lead STQFN Package
JEDEC MO-220



Unit: mm

Symbol	Min	Nom.	Max	Symbol	Min	Nom.	Max
A	0.50	0.55	0.60	D	1.55	1.60	1.65
A1	0.005	-	0.060	E	1.55	1.60	1.65
A2	0.10	0.15	0.20	L	0.26	0.31	0.36
b	0.13	0.18	0.23	L1	0.175	0.225	0.275
e	0.40 BSC			S	0.2 REF		

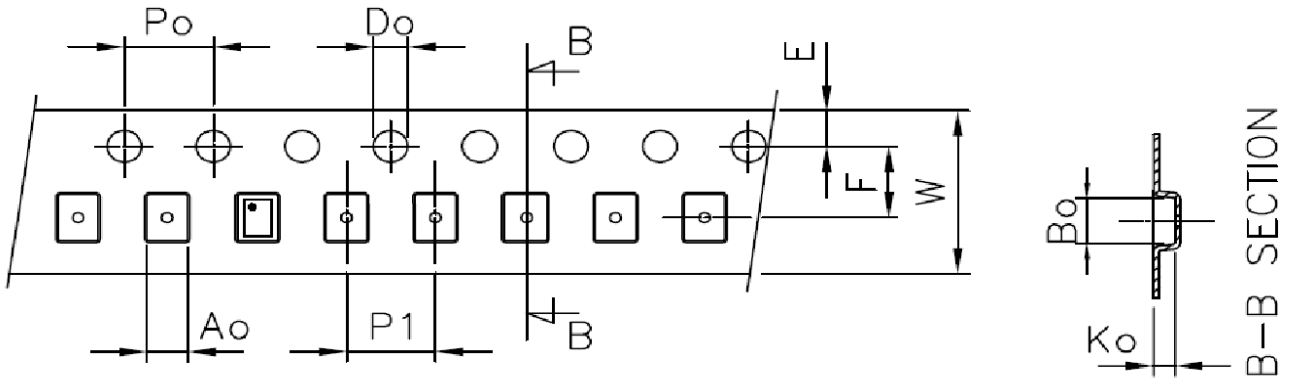
Tape and Reel Specification

Package Type	# of Pins	Nominal Package Size (mm)	Max Units		Reel & Hub Size (mm)	Trailer A		Leader B		Pocket (mm)	
			per reel	per box		Pockets	Length (mm)	Pockets	Length (mm)	Width	Pitch
STQFN 12L FC 0.4P Green	12	1.6x1.6x0.55	3000	3000	178/60	100	400	100	400	8	4

Carrier Tape Drawing and Dimensions

Package Type	Pocket BTM Length (mm)	Pocket BTM Width (mm)	Pocket Depth (mm)	Index Hole Pitch (mm)	Pocket Pitch (mm)	Index Hole Diameter (mm)	Index Hole to Tape Edge (mm)	Index Hole to Pocket Center (mm)	Tape Width (mm)
	A0	B0	K0	P0	P1	D0	E	F	W
STQFN 12L FC 0.4P Green	1.9	1.9	0.8	4	4	1.5	1.75	3.5	8

Refer to EIA-481 Specifications



Recommended Reflow Soldering Profile

Please see IPC/JEDEC J-STD-020: latest revision for reflow profile based on package volume of 1.408 mm^3 (nominal). More information can be found at www.jedec.org.

Datasheet Revision History

Date	Version	Change
06/03/2015	0.10	New design for SLG46110

Silego Website & Support

Silego Technology Website
Silego Technology provides online support via our website at http://www.silego.com/.This website is used as a means to make files and information easily available to customers.

For more information regarding Silego Green products, please visit:
http://greenpak.silego.com/
http://greenpak2.silego.com/
http://greenpak3.silego.com/
http://greenfet.silego.com/
http://greenfet2.silego.com/
http://greenclk.silego.com/

Products are also available for purchase directly from Silego at the Silego Online Store at http://www.silego.com/

Silego Technical Support
Datasheets and errata, application notes and example designs, user guides, and hardware support documents and the latest software releases are available at the Silego website or can be requested directly at info@silego.com.

For specific GreenPAK design or applications questions and support please send e-mail requests to GreenPAK@silego.com

Users of Silego products can receive assistance through several channels:

Online Training
Silego Technology has live training assistance and sales support available at http://www.silego.com/. Please contact us to schedule a 1 on 1 training session with one of our application engineers.

Contact Your Local Sales Representative
Customers can contact their local sales representative or field application engineer (FAE) for support. Local sales offices are also available to help customers. More information regarding your local representative is available at the Silego website or send a request to info@silego.com

Contact Silego Directly
Silego can be contacted directly via e-mail at info@silego.com or user submission form, located at the following URL:
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Other Information
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