A 22 V, 13.1 mΩ, 4 A Integrated Power Switch with V_{IN} Lockout Select and MOSFET Current Monitor Output

General Description

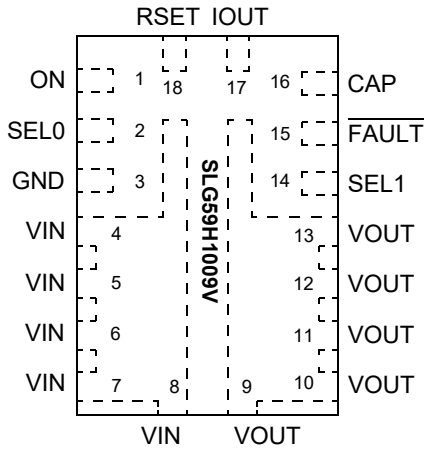
The SLG59H1009V is a high-performance, self-powered 13.1 mΩ NMOS power switch designed for all 4.5 V to 22 V power rails up to 4 A. Using a proprietary MOSFET design, the SLG59H1009V achieves a stable 13.1 mΩ RDS_{ON} across a wide input voltage range. In combining novel FET design and copper pillar interconnects, the SLG59H1009V package also exhibits a low thermal resistance for high-current operation.

Designed to operate over a -40 °C to 85 °C range, the SLG59H1009V is available in a low thermal resistance, RoHS-compliant, 1.6 x 3.0 mm STQFN package.

Features

- UL2367 Certified - File Number E468659
- Maximum Continuous Current: 4 A
- Automatic nFET SOA Protection
- High-performance MOSFET Switch
  - Low RDS_{ON}: 13.1 mΩ at V_{IN} = 22 V
  - Low $\Delta RDS_{ON}/\Delta V_{IN}$: < 0.05 mΩ/V
  - Low $\Delta RDS_{ON}/\Delta T$: < 0.06 mΩ/°C
- Capacitor-adjustable Inrush Current Control
- Two stage Current Limit Protection:
  - Resistor-adjustable Active Current Limit
  - Internal Short-circuit Current limit
- Open Drain $\overline{FAULT}$ Signaling
- MOSFET Current Analog Output Monitor: 10 µA/A
- Fast 4 kΩ Output Discharge
- Pb-Free / Halogen-Free / RoHS Compliant Packaging

Pin Configuration

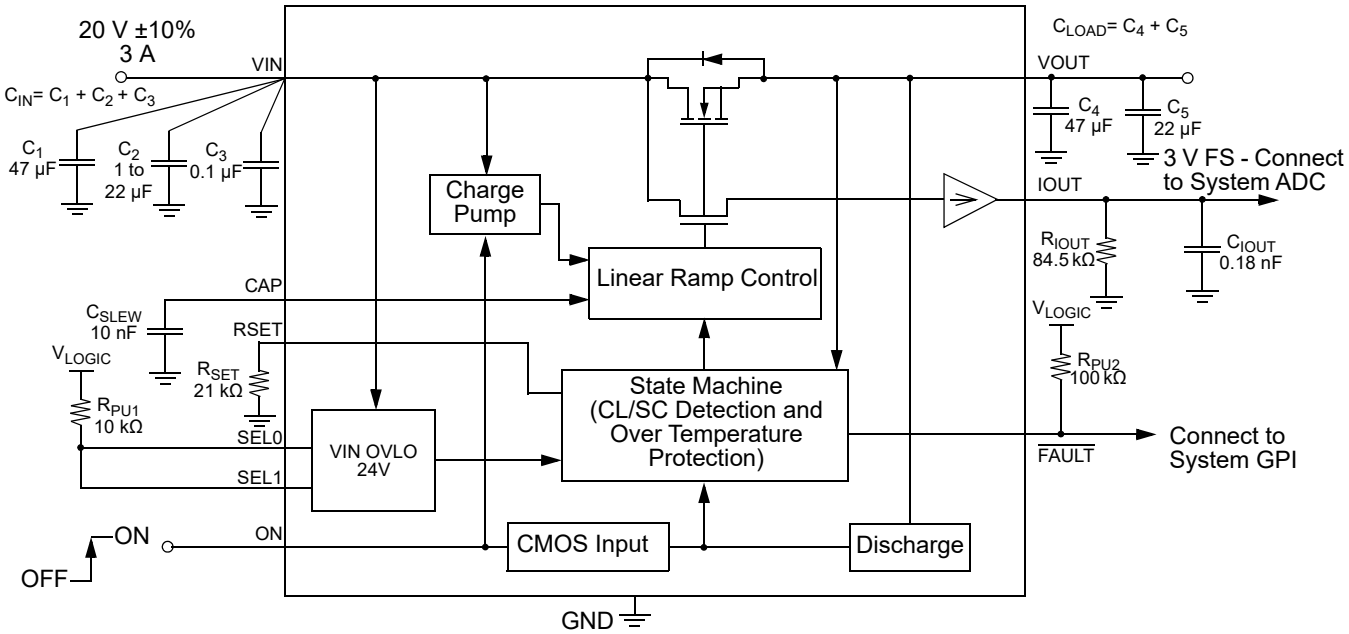


18-pin STQFN
1.6 x 3.0 mm, 0.40mm pitch
(Top View)

Applications

- Power-Rail Switching
- Multifunction Printers
- Large-format Copiers
- Telecommunications Equipment
- High-performance Computing
  - 5 V, 9 V, 12 V, and 20 V Point-of-Load Power Distribution
- Motor Drives

Block Diagram and a 20 V / 3 A Typical Application Circuit



Pin Description

Pin #	Pin Name	Type	Pin Description
1	ON	Input	A low-to-high transition on this pin initiates the operation of the SLG59H1009V's state machine. ON is an asserted HIGH, level-sensitive CMOS input with ON_V_{IL} < 0.3 V and ON_V_{IH} > 0.9 V. As the ON pin input circuit does not have an internal pull-down resistor, connect this pin to a general-purpose output (GPO) of a microcontroller, an application processor, or a system controller – do not allow this pin to be open-circuited.
2	SEL0	Input	As level-sensitive, CMOS inputs with V_{IH} > 1.65 V, the SEL0 (LSB) and the SEL1 (MSB) pins set the V_{IN} overvoltage lockout threshold. A logic HIGH on either pin is achieved by connecting a 10 kΩ external resistor from the pin in question to the system's local logic supply.
3	GND	GND	Pin 3 is the main ground connection for the SLG59H1009V's internal charge pump, its gate driver and current-limit circuits as well as its internal state machine. Therefore, use a short, stout connection from Pin 3 to the system's analog or power plane.
4-8	VIN	MOSFET	VIN supplies the power for the operation of the SLG59H1009V, its internal control circuitry, and the drain terminal of the nFET power switch. With 5 pins fused together at VIN, connect a 47 µF (or larger) low-ESR capacitor from this pin to ground. Capacitors used at VIN should be rated at 50 V or higher.
9-13	VOUT	MOSFET	Source terminal of n-channel MOSFET (5 pins fused for VOUT). Connect a 47 µF (or larger) low-ESR capacitor from this pin to ground. Capacitors used at VOUT should be rated at 50 V or higher.
14	SEL1	Input	Please see SEL0 Pin Description above
15	$\overline{FAULT}$	Output	An open drain output, $\overline{FAULT}$ is asserted within $T\overline{FAULT}_{LOW}$ when a V_{IN} overvoltage, a current-limit, or an over-temperature condition is detected. $\overline{FAULT}$ is deasserted within $T\overline{FAULT}_{HIGH}$ when the fault condition is removed. Connect an 100 kΩ external resistor from the $\overline{FAULT}$ pin to local system logic supply.
16	CAP	Output	A low-ESR, stable dielectric, ceramic surface-mount capacitor connected from CAP pin to GND sets the V_{OUT} slew rate and overall turn-on time of the SLG59H1009V. For best performance, the range for C_{SLEW} values are 10 nF ≤ C_{SLEW} ≤ 20 nF – please see typical characteristics for additional information. Capacitors used at the CAP pin should be rated at 10 V or higher. Please consult Applications Section on how to select C_{SLEW} based on V_{OUT} slew rate and loading conditions.
17	IOUT	Output	IOUT is the SLG59H1009V's power MOSFET load current monitor output. As an analog current output, this signal when applied to a ground-reference resistor generates a voltage proportional to the current through the n-channel MOSFET. The I_{OUT} transfer characteristic is typically 10 µA/A with a voltage compliance range of 0.5 V ≤ V_{IOUT} ≤ 4 V. Optimal I_{OUT} linearity is exhibited for 0.5 A ≤ I_{DS} ≤ 4 A. In addition, it is recommended to bypass the IOUT pin to GND with a 0.18 nF capacitor.
18	RSET	Input	A 1%-tolerance, metal-film 21 kΩ resistor sets the active current limit of the SLG59H1009V to 4.5 A.

Ordering Information

Part Number	Type	Production Flow
SLG59H1009V	STQFN 18L FC	Industrial, -40 °C to 85 °C
SLG59H1009VTR	STQFN 18L FC (Tape and Reel)	Industrial, -40 °C to 85 °C

Absolute Maximum Ratings

Parameter	Description	Conditions	Min.	Typ.	Max.	Unit
V_{IN} to GND	Power Switch Input Voltage to GND	Continuous	-0.3	--	30	V
		Maximum pulsed V_{IN}, pulse width < 0.1 s	--	--	32	V
V_{OUT} to GND	Power Switch Output Voltage to GND		-0.3	--	VIN	V
ON, SEL[1,0], CAP, RSET, IOUT, and FAULT to GND	ON, SEL[1,0], CAP, RSET, IOUT, and FAULT Pin Voltages to GND		-0.3	--	7	V
T_S	Storage Temperature		-65	--	150	°C
ESD_{HBM}	ESD Protection	Human Body Model	2000	--	--	V
ESD_{CDM}	ESD Protection	Charged Device Model	500	--	--	V
MSL	Moisture Sensitivity Level			1		
θ_{JA}	Thermal Resistance	1.6 x 3.0 mm 18L STQFN; Determined with the device mounted onto a 1 in^2, 1 oz. copper pad of FR-4 material	--	40	--	°C/W
MOSFET IDS_{CONT}	Continuous Current from VIN to VOUT	T_J < 150 °C	--	--	4	A
MOSFET IDS_{PEAK}	Peak Current from VIN to VOUT	Maximum pulsed switch current, pulse width < 1 ms	--	--	5	A

Note: Stresses greater than those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect reliability.

Electrical Characteristics

V_{IN} = 22 V; C_{IN} = 47 µF, T_A = -40 °C to 85 °C, unless otherwise noted. Typical values are at T_A = 25 °C

Parameter	Description	Conditions	Min.	Typ.	Max.	Unit
V_{IN}	Operating Input Voltage		--	20	22	V
$V_{IN(OVLO)}$	V_{IN} Overvoltage Lockout Threshold	V_{IN} ↑; SEL[1,0] = [1,1]	22.7	24	25.2	V
$V_{IN(UVLO)}$	V_{IN} Undervoltage Lockout Threshold	V_{IN} ↓	2.4	--	3.8	V
I_Q	Quiescent Supply Current	ON = HIGH; I_{DS} = 0 A	--	0.5	0.6	mA
I_{SHDN}	OFF Mode Supply Current	ON = LOW; I_{DS} = 0 A	--	1	3	µA
RDS_{ON}	ON Resistance	T_A = 25 °C; I_{DS} = 0.1 A	--	13.1	14	mΩ
		T_A = 85 °C; I_{DS} = 0.1 A	--	16	16.5	mΩ
MOSFET IDS	Current from VIN to VOUT	Continuous	--	--	4	A
I_{LIMIT}	Active Current Limit, I_{ACL}	V_{OUT} > 0.5 V; R_{SET} = 21 kΩ	4.2	4.5	4.9	A
	Short-circuit Current Limit, I_{SCL}	V_{OUT} < 0.5 V	--	0.5	--	A
T_{ACL}	Active Current Limit Response Time		--	120	--	µs
$R_{DISCHRG}$	Output Discharge Resistance		3.5	4.4	5.3	kΩ
I_{OUT}	MOSFET Current Analog Monitor Output	I_{DS} = 1 A	9.3	10	10.7	µA
		I_{DS} = 3 A	28.5	30	31.5	µA
T_{IOUT}	I_{OUT} Response Time to Change in Main MOSFET Current	C_{IOUT} = 180 pF; Step load 0 to 2.4 A; 0% to 90% I_{OUT}	--	45	--	µs

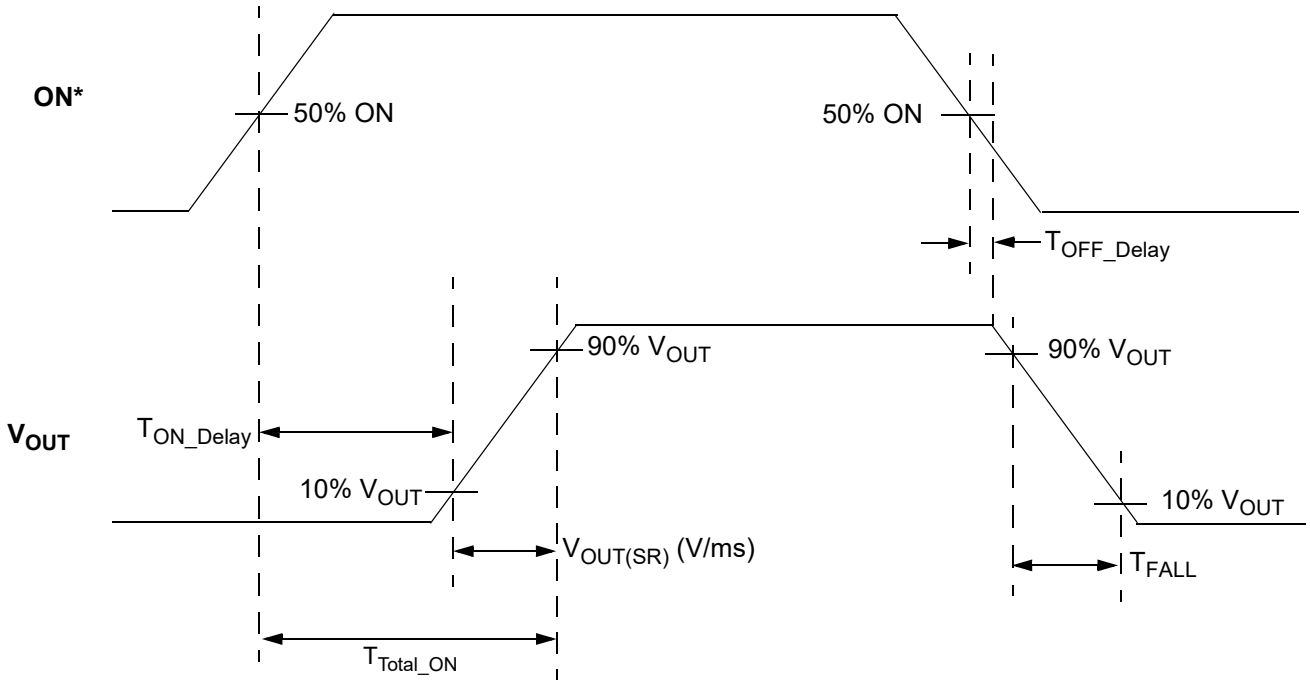
Electrical Characteristics (continued)

V_{IN} = 22 V; C_{IN} = 47 µF, T_A = -40 °C to 85 °C, unless otherwise noted. Typical values are at T_A = 25 °C

Parameter	Description	Conditions	Min.	Typ.	Max.	Unit
C_{LOAD}	Output Load Capacitance	C_{LOAD} connected from VOUT to GND	--	47	--	µF
T_{ON_Delay}	ON Delay Time	50% ON to 10% V_{OUT} ↑; V_{IN} = 22 V; C_{SLEW} = 10 nF; R_{LOAD} = 100 Ω, C_{LOAD} = 10µF	--	0.7	1.2	ms
T_{Total_ON}	Total Turn On Time	50% ON to 90% V_{OUT} ↑	Set by External C_{SLEW}[1]			ms
		50% ON to 90% V_{OUT} ↑; V_{IN} = 22 V; C_{SLEW} = 10 nF; R_{LOAD} = 100 Ω, C_{LOAD} = 10 µF	--	5	8	ms
$V_{OUT(SR)}$	V_{OUT} Slew rate	10% V_{OUT} to 90% V_{OUT} ↑	Set by External C_{SLEW}[1]			V/ms
		10% V_{OUT} to 90% V_{OUT} ↑; V_{IN} = 22 V; C_{SLEW} = 10 nF; R_{LOAD} = 100 Ω, C_{LOAD} = 10 µF	2.7	3.2	3.9	V/ms
T_{OFF_Delay}	OFF Delay Time	50% ON to V_{OUT} Fall Start ↓; V_{IN} = 22 V; R_{LOAD} = 100 Ω, No C_{LOAD}	--	15	--	µs
T_{FALL}	V_{OUT} Fall Time	90% V_{OUT} to 10% V_{OUT}; ON = HIGH-to-LOW; V_{IN} = 22 V; R_{LOAD} = 100 Ω, No C_{LOAD}	10.4	12.7	14.3	µs
$T\overline{FAULT}_{LOW}$	$\overline{FAULT}$ Assertion Time	Abnormal Step Load Current event to $\overline{FAULT}$↓; I_{ACL} = 4.5 A; V_{IN} = 22 V; R_{SET} = 21 kΩ; switch in 5 Ω load	--	80	--	µs
$T\overline{FAULT}_{HIGH}$	$\overline{FAULT}$ De-assertion Time	Delay to $\overline{FAULT}$↑ after fault condition is removed; I_{ACL} = 4.5 A; V_{IN} = 22 V; R_{SET} = 21 kΩ; switch out 5 Ω load	--	180	--	µs
$\overline{FAULT}_{VOL}$	$\overline{FAULT}$ Output Low Voltage	$I_{\overline{FAULT}}$ = 1 mA	--	0.2	--	V
ON_V_{IH}	ON Pin Input High Voltage		0.9	--	5	V
ON_V_{IL}	ON Pin Input Low Voltage		-0.3	0	0.3	V
SEL[1,0]_V_{IH}	SEL[1,0] pins Input High Voltage		1.65	--	4.5	V
$I_{ON(Leakage)}$	ON Pin Leakage Current	1 V ≤ ON ≤ 5 V or ON = GND	--	--	1	µA
$THERM_{ON}$	Thermal Protection Shutdown Threshold		--	125	--	°C
$THERM_{OFF}$	Thermal Protection Restart Threshold		--	100	--	°C

Notes:
1. Refer to typical Timing Parameter vs. C_{SLEW} performance charts for additional information when available.

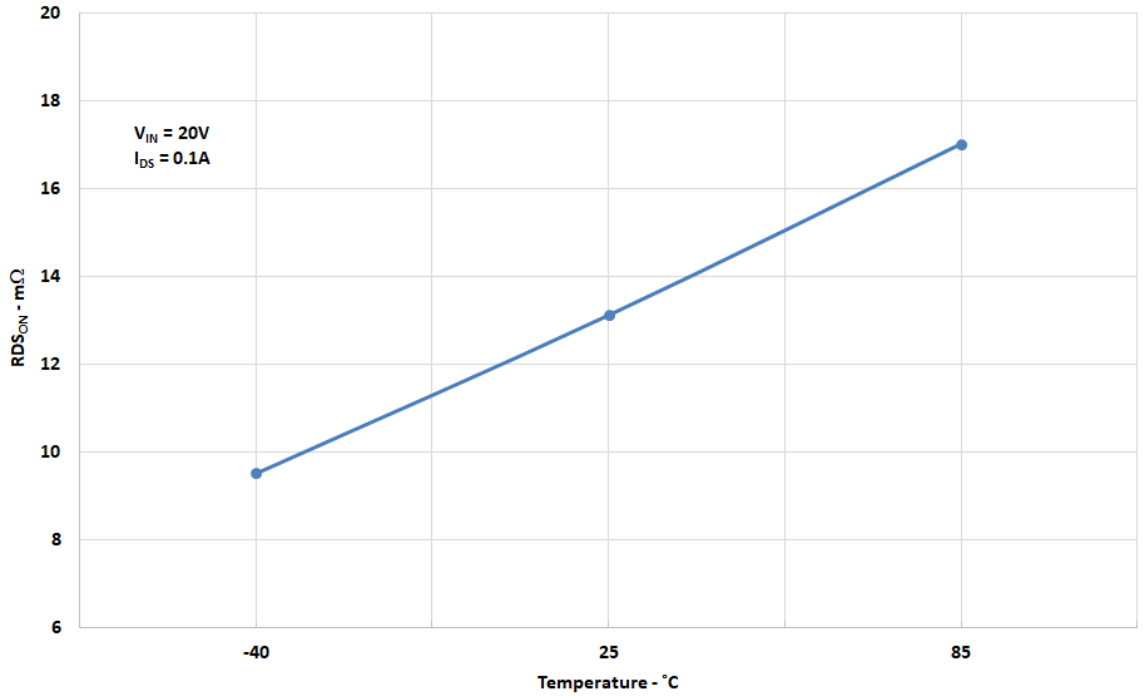
T_{Total_ON}, T_{ON_Delay} and Slew Rate Measurement



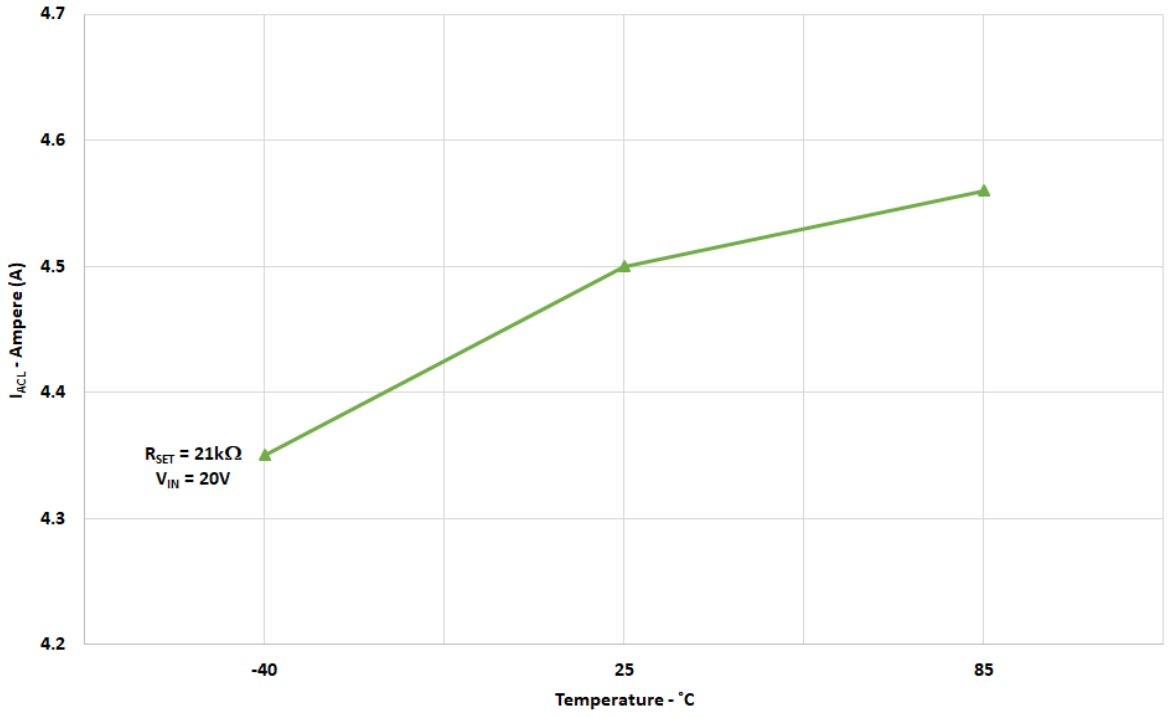
*Rise and Fall Times of the ON Signal are 100 ns

Typical Performance Characteristics

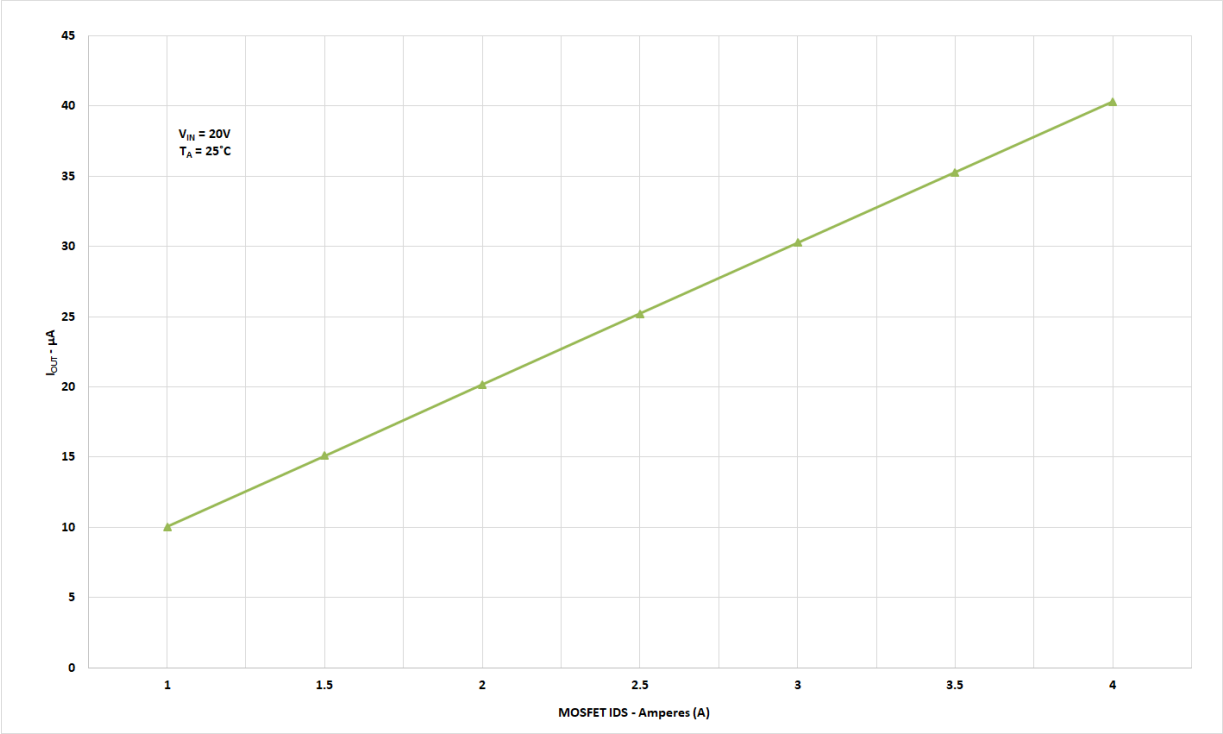
RDS_{ON} vs. Temperature



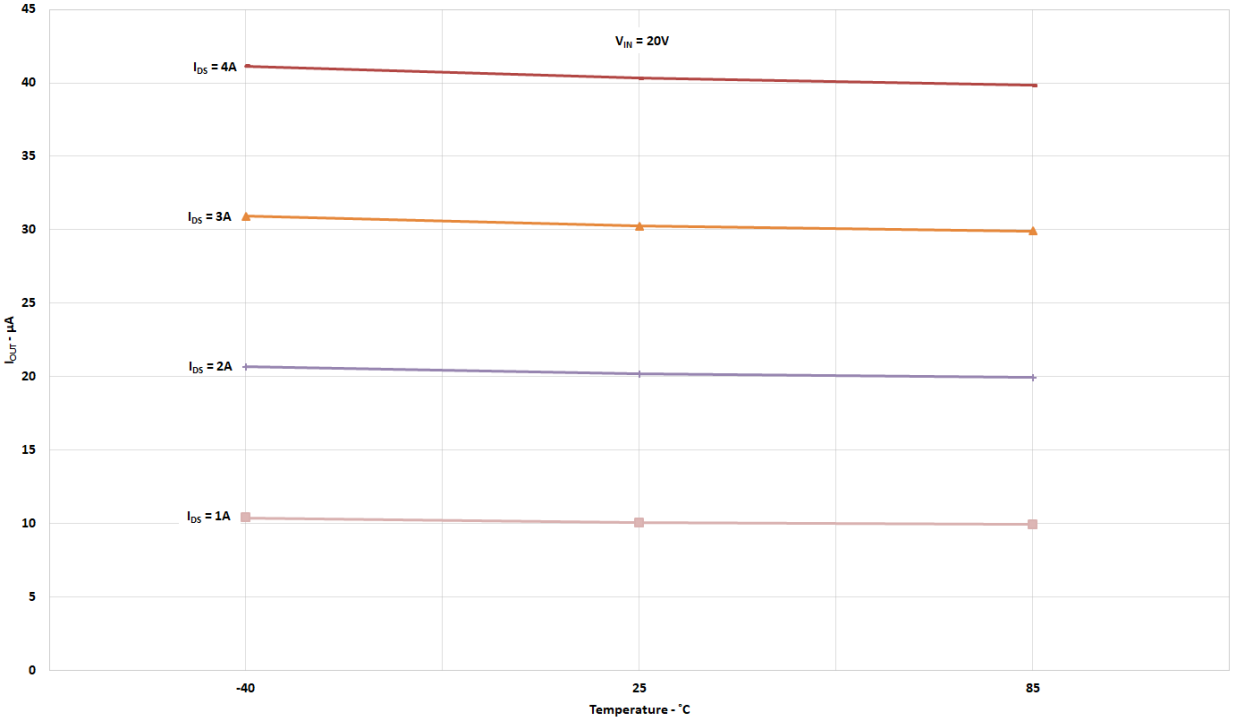
I_{ACL} vs. Temperature



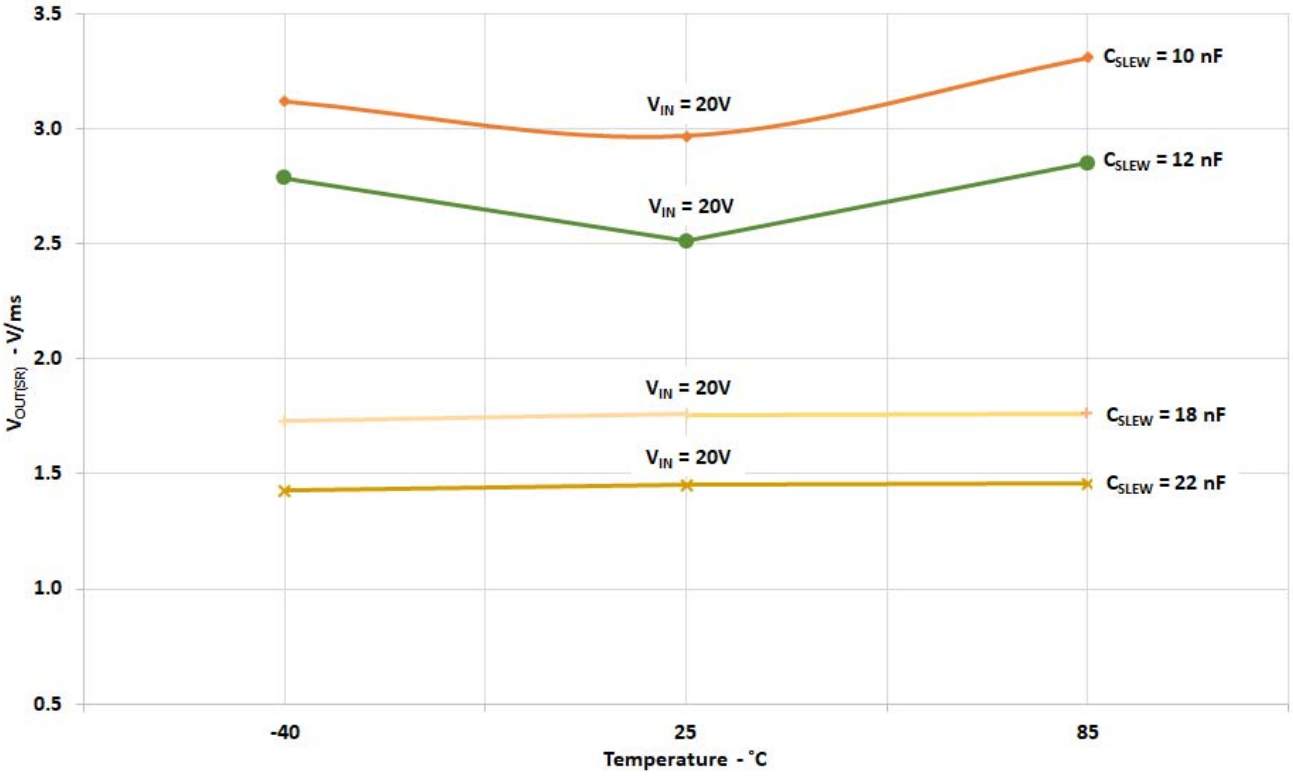
I_{OUT} vs. MOSFET IDS



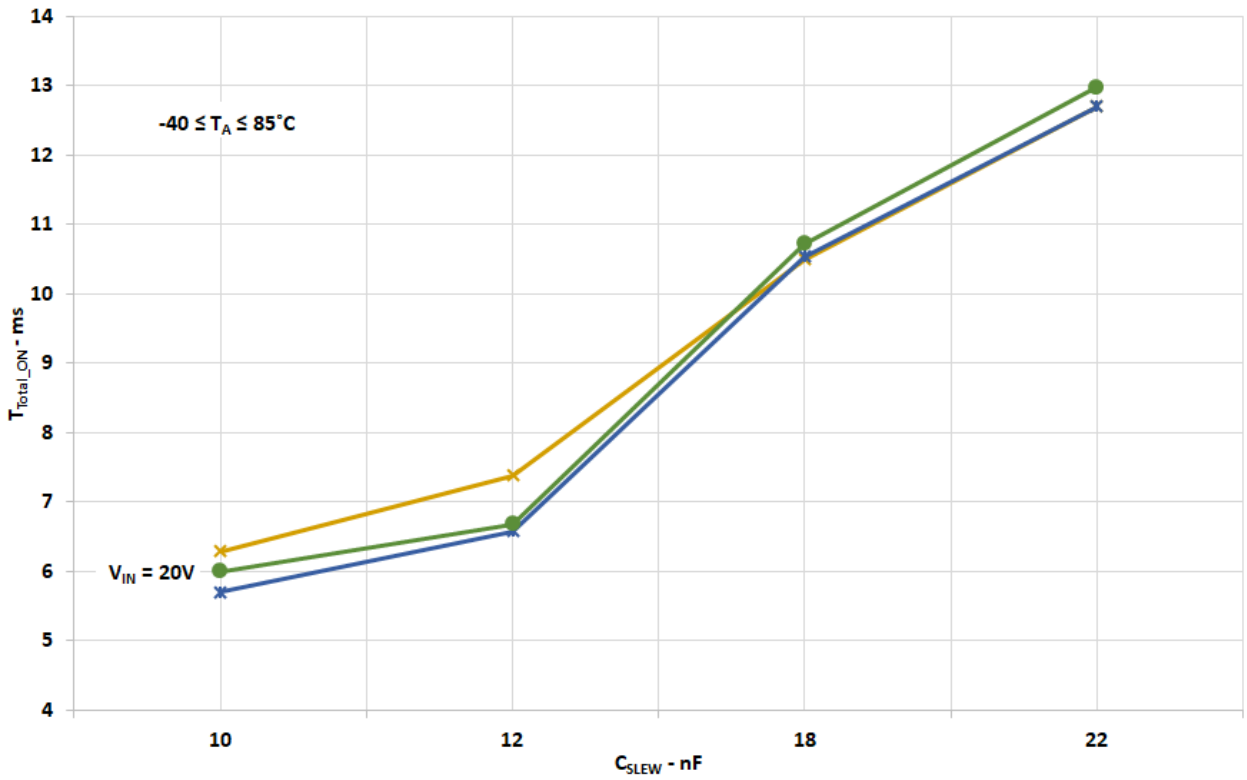
I_{OUT} vs. Temperature and MOSFET IDS



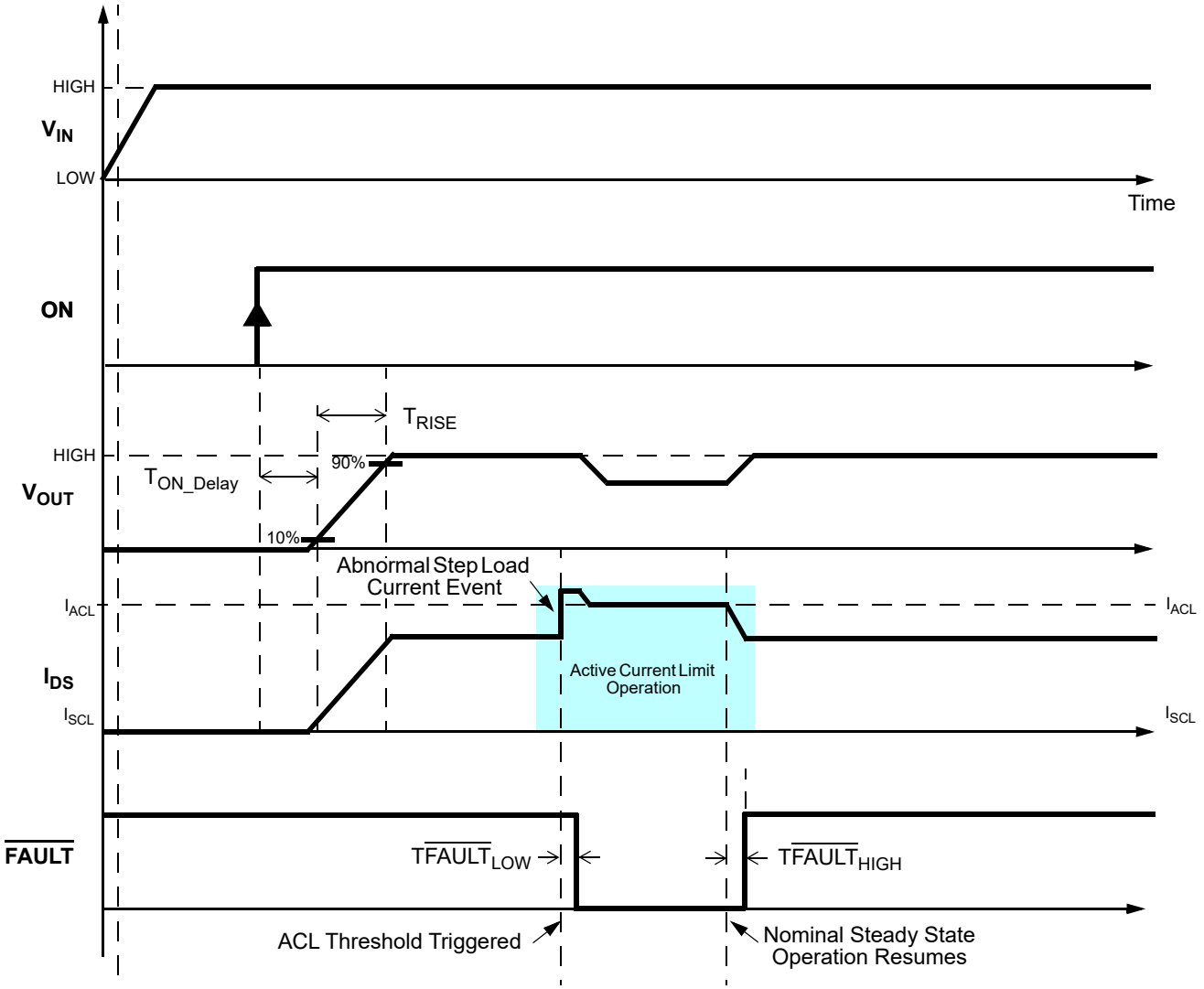
V_{OUT} Slew Rate vs. Temperature and C_{SLEW}



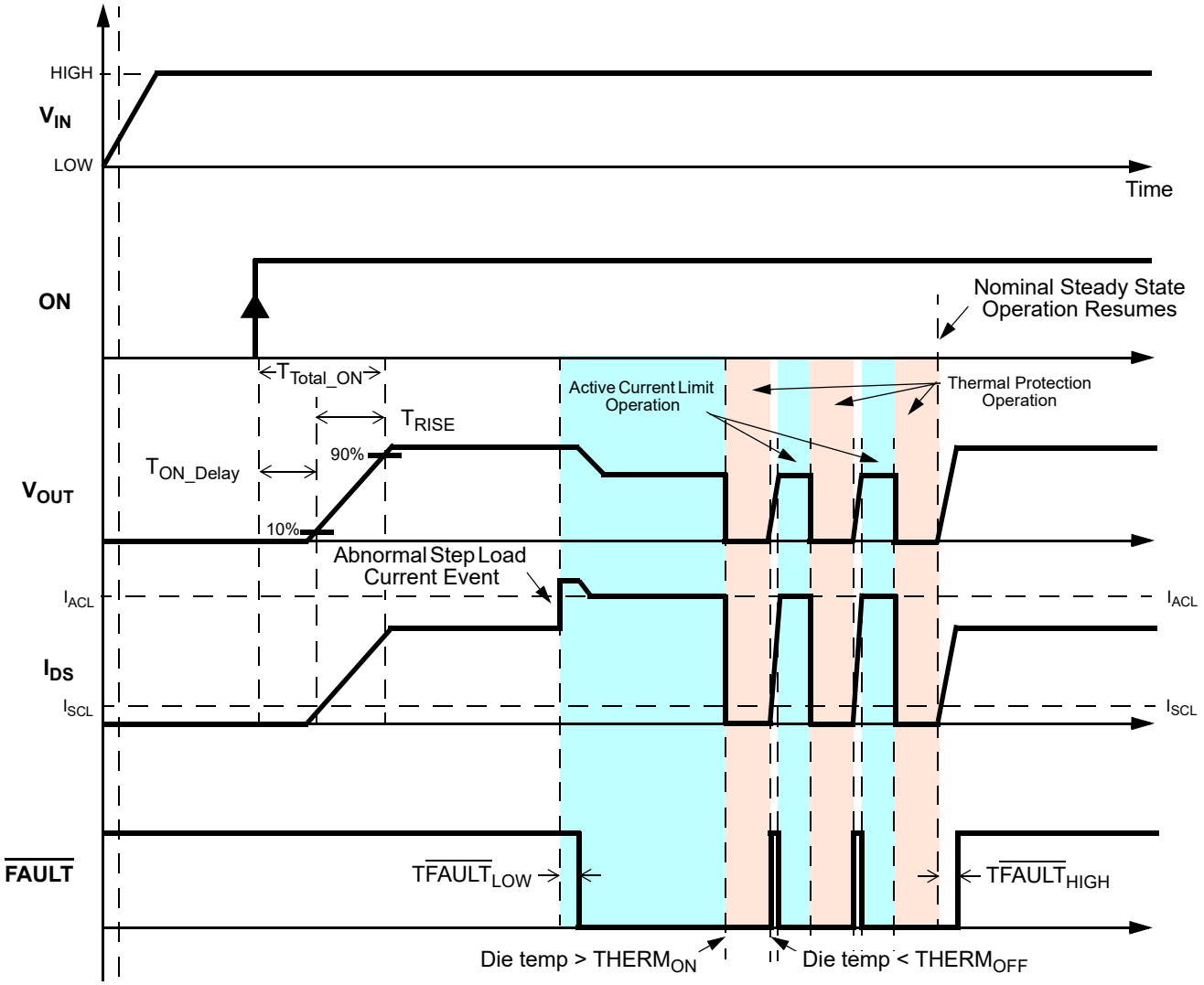
T_{Total_ON} vs. C_{SLEW} and Temperature



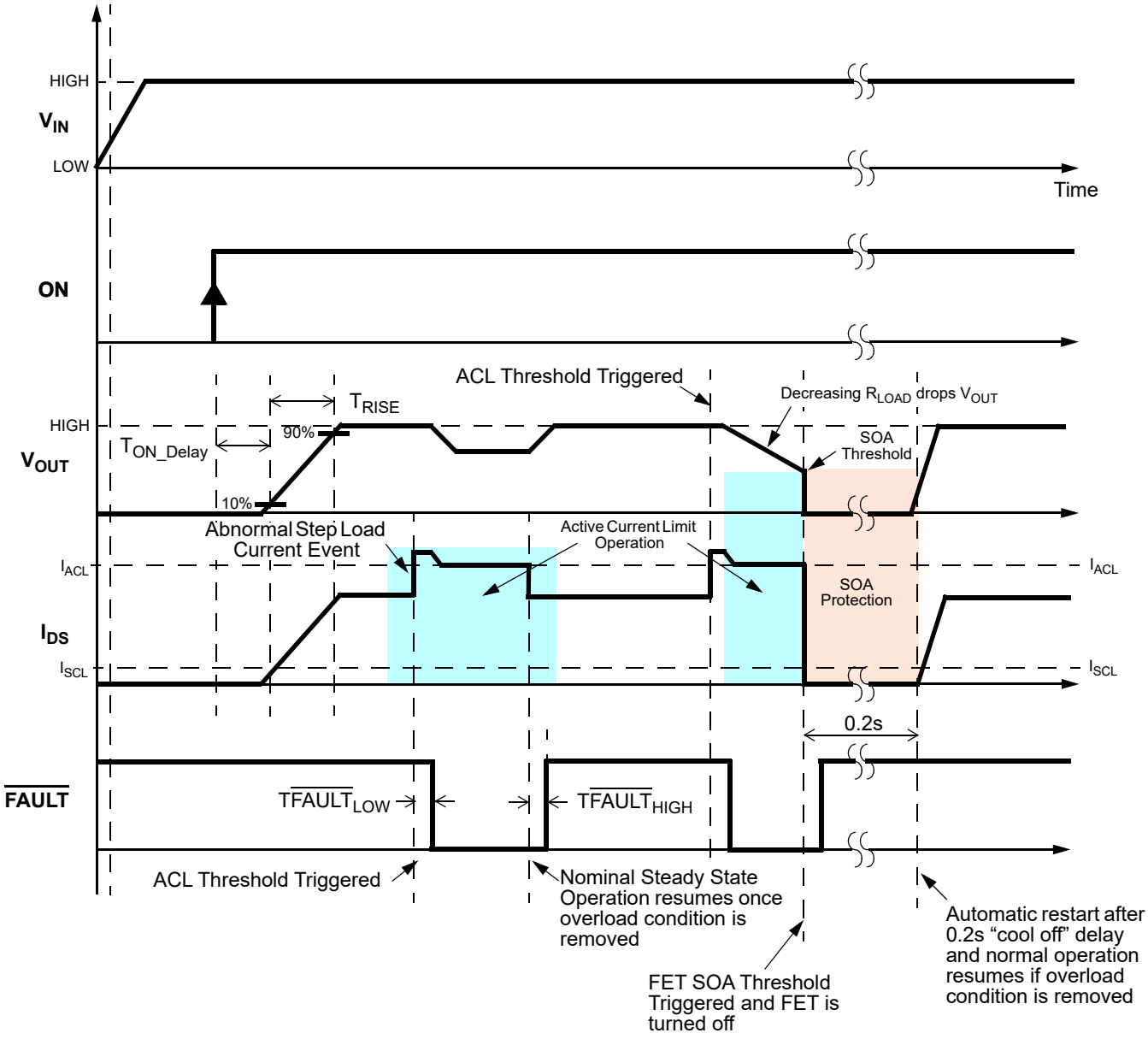
Timing Diagram - Basic Operation including Active Current Limit Protection



Timing Diagram - Active Current Limit & Thermal Protection Operation



Timing Diagram - Basic Operation including Active Current + Internal FET SOA Protection



SLG59H1009V Application Diagram

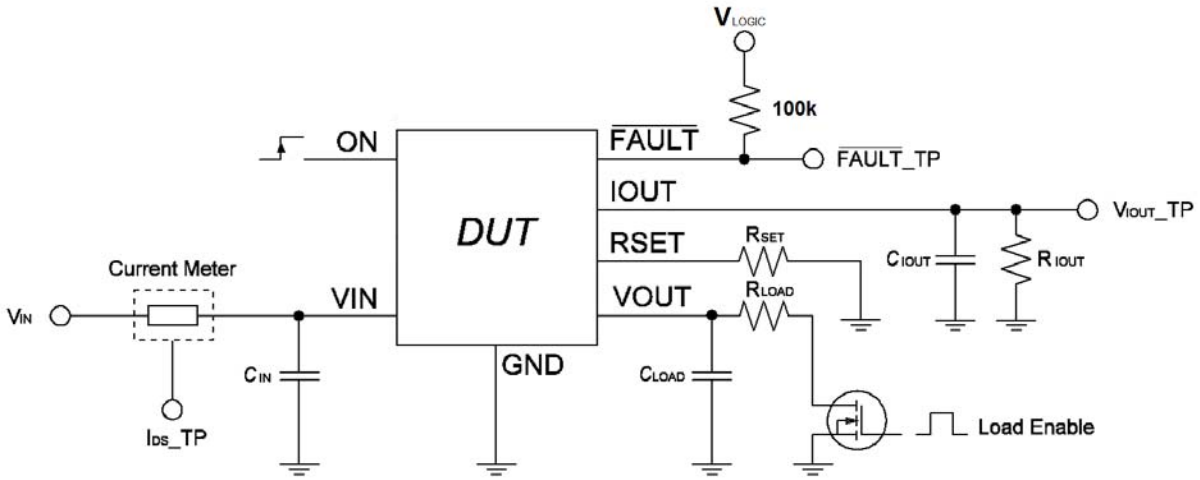


Figure 1. Test setup Application Diagram

Typical Turn-on Waveforms

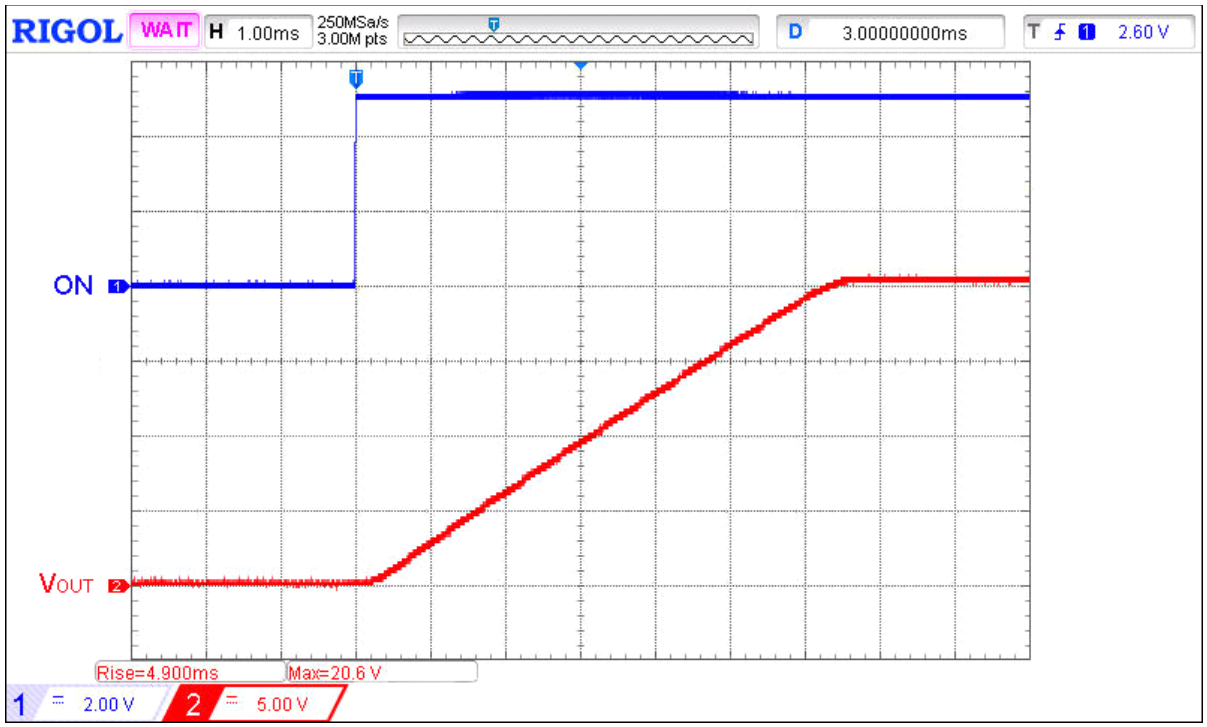


Figure 2. Typical Turn ON operation waveform for V_{IN} = 20 V, C_{SLEW} = 10 nF, C_{LOAD} = 10 µF, R_{LOAD} = 100 Ω

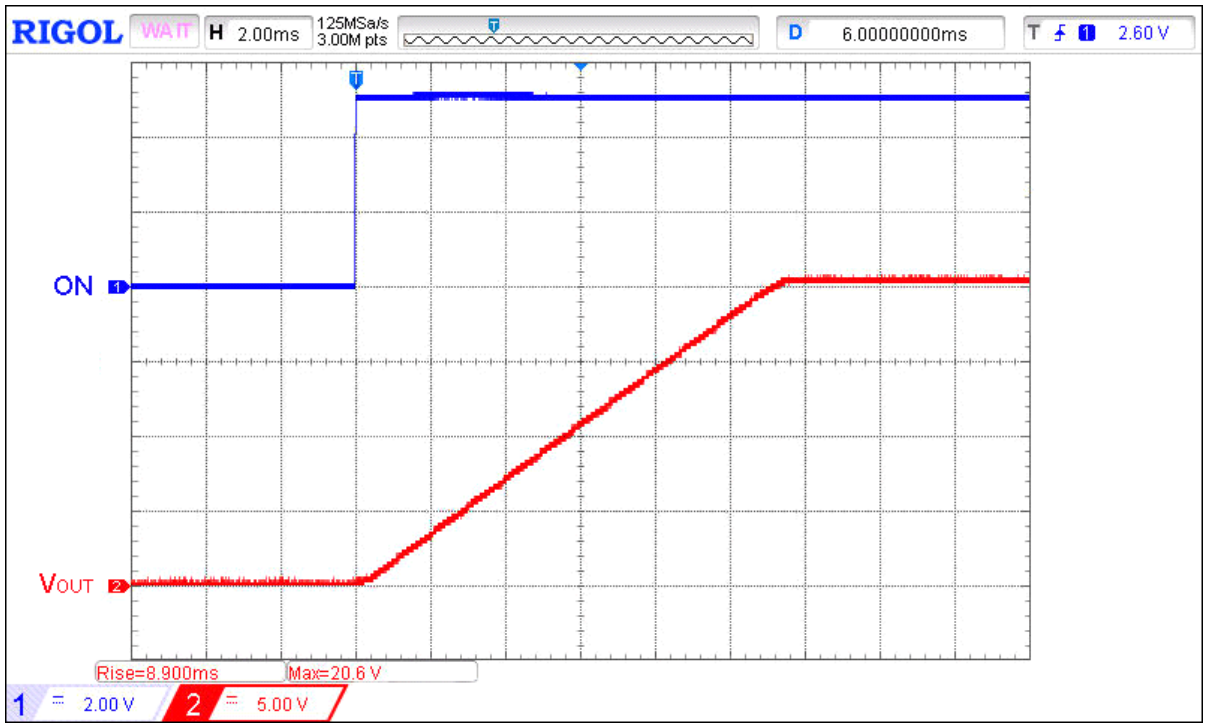


Figure 3. Typical Turn ON operation waveform for V_{IN} = 20 V, C_{SLEW} = 18 nF, C_{LOAD} = 10 µF, R_{LOAD} = 100 Ω

Typical Turn-off Waveforms

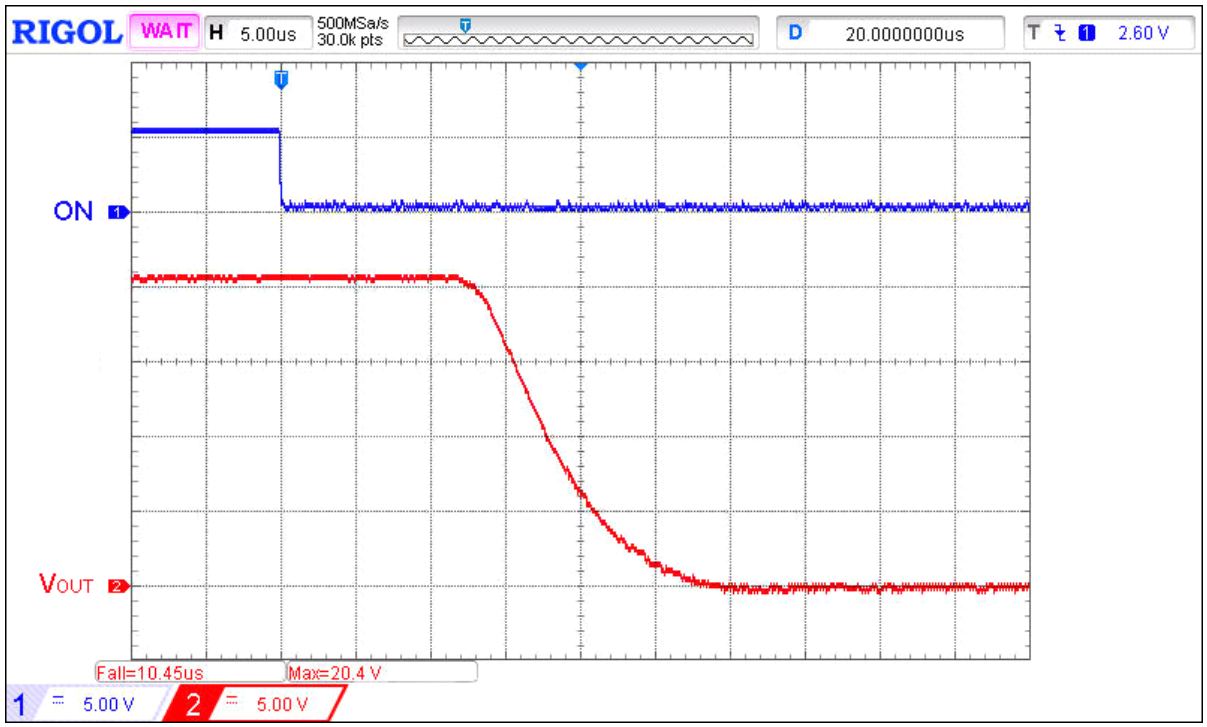


Figure 4. Typical Turn OFF operation waveform for V_{IN} = 20 V, C_{SLEW} = 10 nF, no C_{LOAD} , R_{LOAD} = 100 Ω

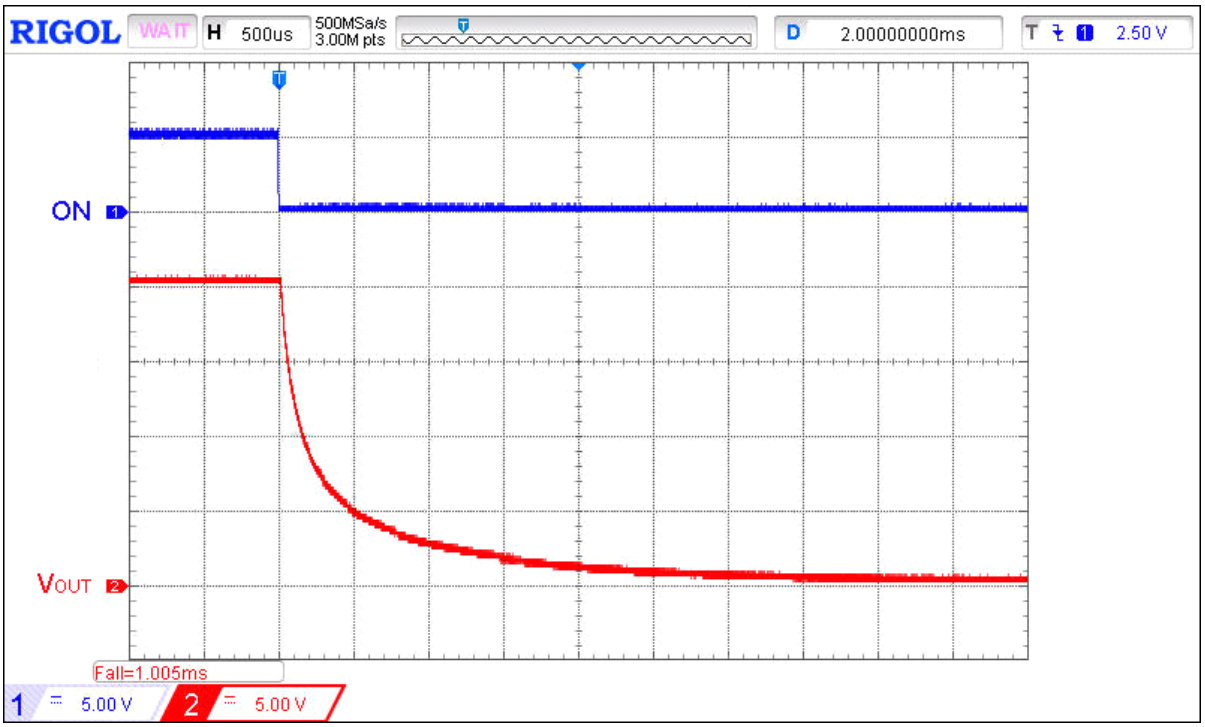


Figure 5. Typical Turn OFF operation waveform for V_{IN} = 20 V, C_{SLEW} = 10 nF, C_{LOAD} = 10 µF, R_{LOAD} = 100 Ω

Typical SOA Waveforms

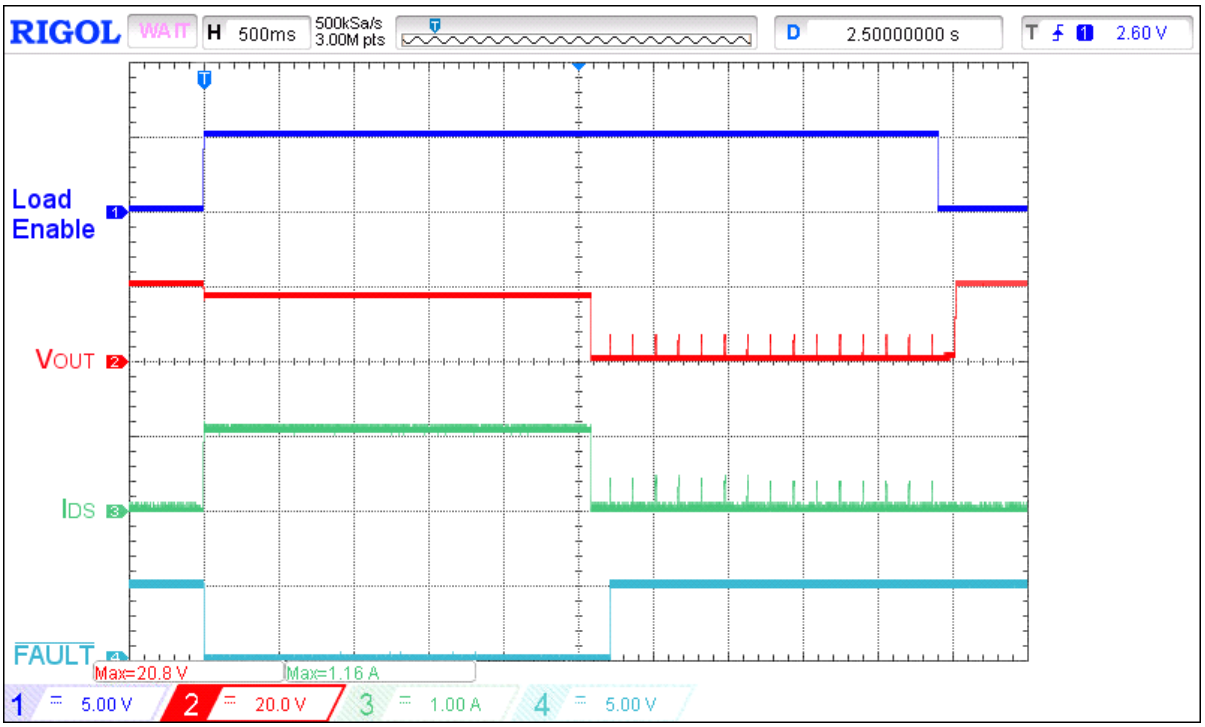


Figure 6. Thermally induced SOA shutdown for V_{IN} = 20 V, C_{LOAD} = 10 µF, I_{ACL} = 1 A, R_{SET} = 91 kΩ

Typical $\overline{\text{FAULT}}$ Operation Waveforms

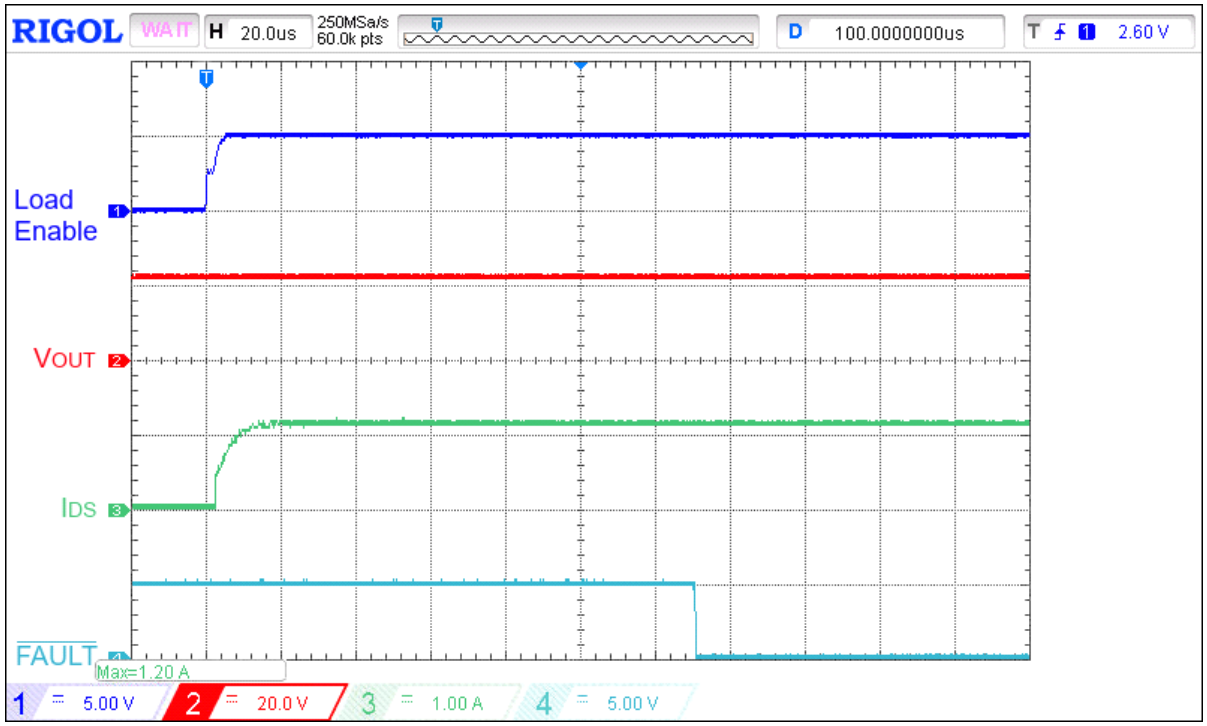


Figure 7. Typical $\overline{\text{FAULT}}$ assertion waveform for V_{IN} = 20 V, C_{LOAD} = 10 µF, I_{ACL} = 1 A, R_{SET} = 91 kΩ, switch in 20 Ω load

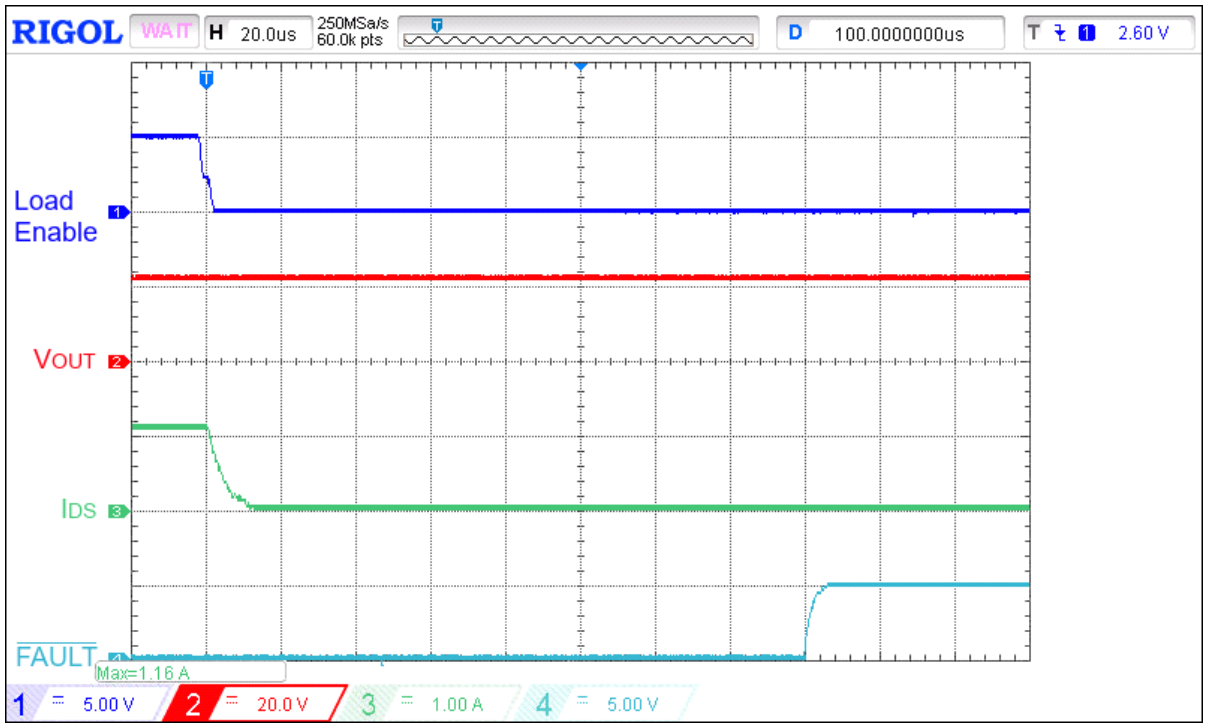


Figure 8. Typical $\overline{\text{FAULT}}$ de-assertion waveform for V_{IN} = 20 V, C_{LOAD} = 10 µF, I_{ACL} = 1 A, R_{SET} = 91 kΩ, switch out 20 Ω load

Applications Information

HFET1 Safe Operating Area Explained

Dialog's HFET1 integrated power controllers incorporate a number of internal protection features that prevents them from damaging themselves or any other circuit or subcircuit downstream of them. One particular protection feature is their Safe Operation Area (SOA) protection. SOA protection is automatically activated under overpower and, in some cases, under overcurrent conditions. Overpower SOA is activated if package power dissipation exceeds an internal 5W threshold longer than 2.5 ms. HFET1 devices will quickly switch off (open circuit) upon overpower detection and automatically resume (close) nominal operation once overpower condition no longer exists.

One possible way to have an overpower condition trigger SOA protection is when HFET1 products are enabled into heavy output resistive loads and/or into large load capacitors. It is under these conditions to follow carefully the "Safe Start-up Loading" guidance in the Applications section of the datasheet. During an overcurrent condition, HFET1 devices will try to limit the output current to the level set by the external R_{SET} resistor. Limiting the output current, however, causes an increased voltage drop across the FET's channel because the FET's RDS_{ON} increased as well. Since the FET's RDS_{ON} is larger, package power dissipation also increases. If the resultant increase in package power dissipation is higher/equal than 5 W for longer than 2.5 ms, internal SOA protection will be triggered and the FET will open circuit (switch off). Every time SOA protection is triggered, all HFET1 devices will automatically attempt to resume nominal operation after 160 ms.

Safe Start-up Condition

SLG59H1009V has built-in protection to prevent over-heating during start-up into a heavy load. Overloading the VOUT pin with a capacitor and a resistor may result in non-monotonic V_{OUT} ramping. In general, under light loading on VOUT, V_{OUT} ramping can be controlled with C_{SLEW} value. The following equation serves as a guide:

$$C_{SLEW} = \frac{T_{RISE}}{V_{IN}} \times 4.9\ \mu A \times \frac{20}{3}$$

where
T_{RISE} = Total rise time from 10% V_{OUT} to 90% V_{OUT}
V_{IN} = Input Voltage
C_{SLEW} = Capacitor value for CAP pin

When capacitor and resistor loading on VOUT during start up, the following tables will ensure V_{OUT} ramping is monotonic without triggering internal protection:

Safe Start-up Loading for V_{IN} = 22 V (Monotonic Ramp)			
Slew Rate (V/ms)	**C_{SLEW} (nF)[2]**	**C_{LOAD} (µF)**	**R_{LOAD} (Ω)**
0.5	66.7	500	80
1.0	33.3	250	80
1.5	22.2	160	80
2.0	16.7	120	80
2.5	13.3	100	80

Note 2: Select the closest-value tolerance capacitor.

Power Dissipation

The junction temperature of the SLG59H1009V depends on different factors such as board layout, ambient temperature, and other environmental factors. The primary contributor to the increase in the junction temperature of the SLG59H1009V is the power dissipation of its power MOSFET. Its power dissipation and the junction temperature in nominal operating mode can be calculated using the following equations:

$$PD = RDS_{ON} \times I_{DS}^2$$

where:

PD = Power dissipation, in Watts (W)
RDS_{ON} = Power MOSFET ON resistance, in Ohms (Ω)
I_{DS} = Output current, in Amps (A)

and

$$T_J = PD \times \theta_{JA} + T_A$$

where:

T_J = Junction temperature, in Celsius degrees (°C)
θ_{JA} = Package thermal resistance, in Celsius degrees per Watt (°C/W)
T_A = Ambient temperature, in Celsius degrees (°C)

In current-limit mode, the SLG59H1009V's power dissipation can be calculated by taking into account the voltage drop across the power switch (V_{IN}-V_{OUT}) and the magnitude of the output current in current-limit mode (I_{ACL}):

$$PD = (V_{IN}\text{-}V_{OUT}) \times I_{ACL} \text{ or}$$

$$PD = (V_{IN} – (R_{LOAD} \times I_{ACL})) \times I_{ACL}$$

where:

PD = Power dissipation, in Watts (W)
V_{IN} = Input Voltage, in Volts (V)
R_{LOAD} = Load Resistance, in Ohms (Ω)
I_{ACL} = Output limited current, in Amps (A)
$V_{OUT} = R_{LOAD} \times I_{ACL}$

Layout Guidelines:

1. Since the VIN and VOUT pins dissipate most of the heat generated during high-load current operation, it is highly recommended to make power traces as short, direct, and wide as possible. A good practice is to make power traces with an absolute minimum widths of 15 mils (0.381 mm) per Ampere. A representative layout, shown in Figure 9, illustrates proper techniques for heat to transfer as efficiently as possible out of the device;

2. To minimize the effects of parasitic trace inductance on normal operation, it is recommended to connect input C_{IN} and output C_{LOAD} low-ESR capacitors as close as possible to the SLG59H1009V's VIN and VOUT pins;

3. The GND pin should be connected to system analog or power ground plane.

4. 2 oz. copper is recommended for high current operation.

SLG59H1009V Evaluation Board:

A HFET1 Evaluation Board for SLG59H1009V is designed according to the statements above and is illustrated on Figure 9. Please note that evaluation board has D_Sense and S_Sense pads. They cannot carry high currents and dedicated only for RDS_{ON} evaluation.

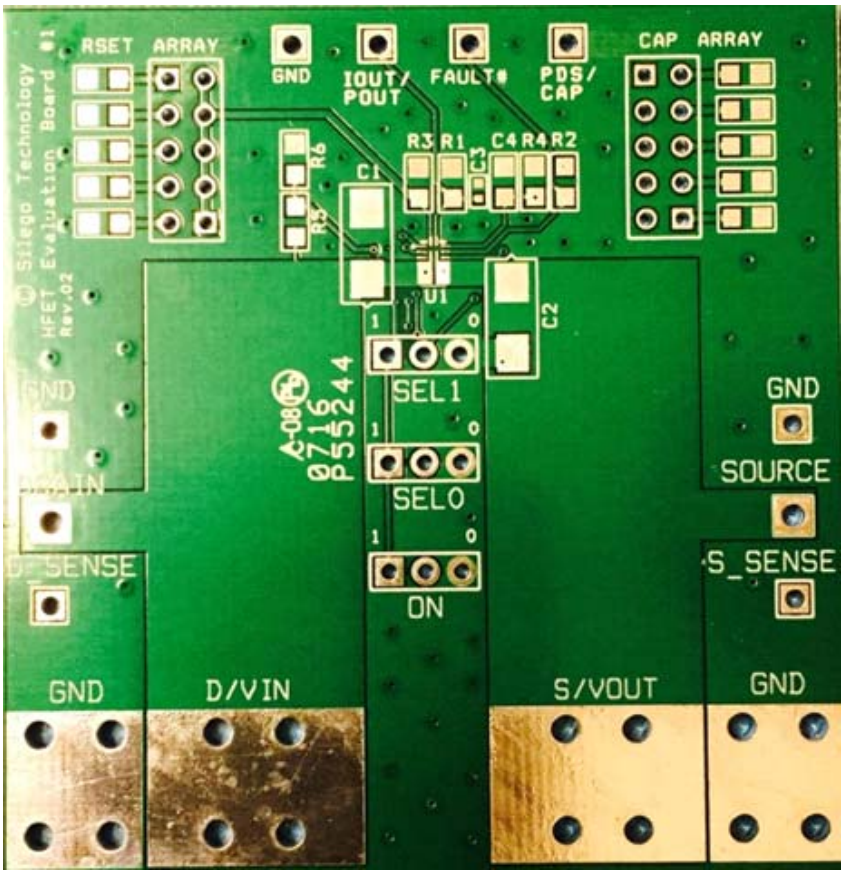


Figure 9. SLG59H1009V Evaluation Board

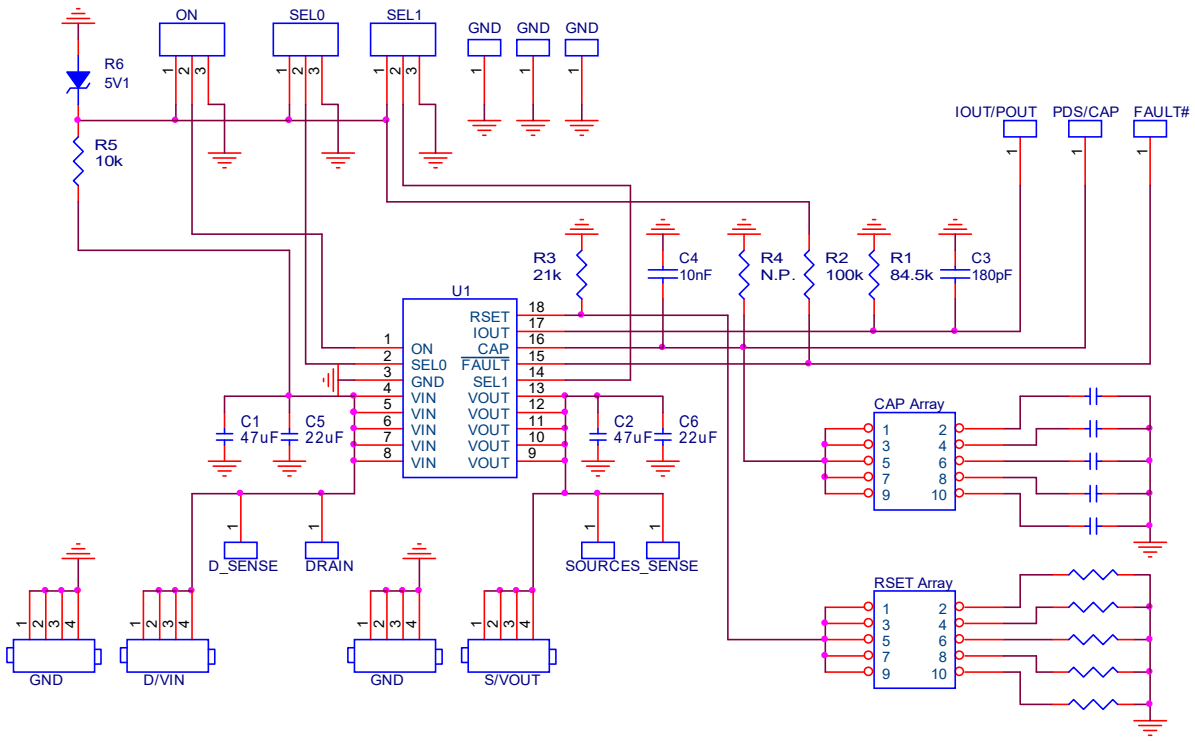


Figure 10. SLG59H1009V Evaluation Board Connection Circuit

Basic Test Setup and Connections

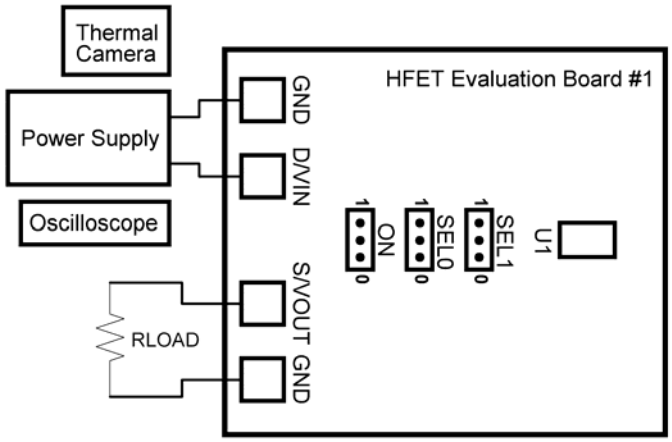


Figure 11. SLG59H1009V Evaluation Board Connection Circuit

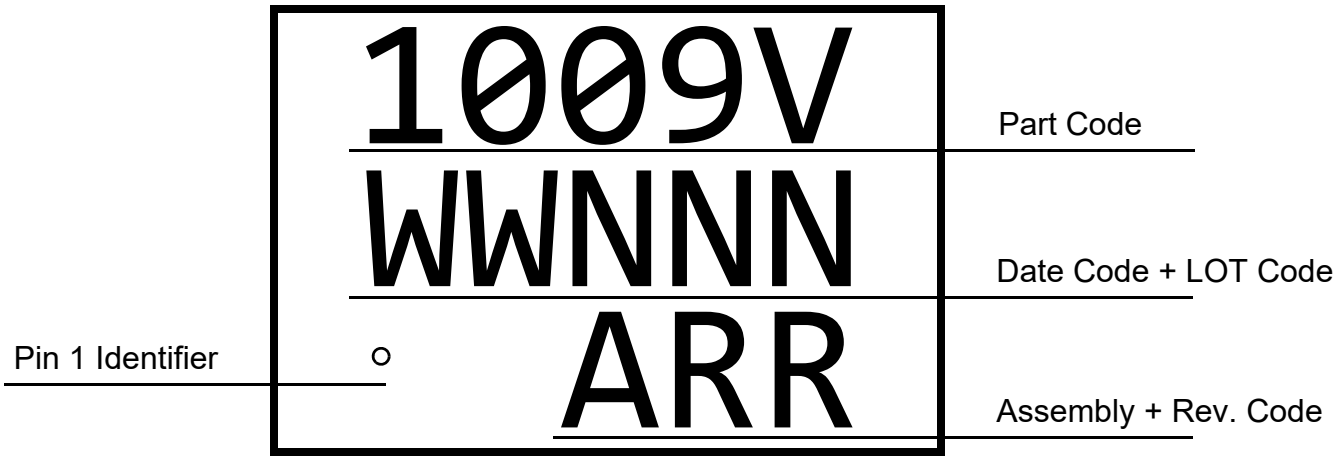
EVB Configuration

1. Connect oscilloscope probes to D/VIN, S/VOUT, ON, etc.;

2. Turn on Power Supply and set desired V_{IN} from 4.5 V ... 22 V range;

3 .Toggle the ON signal High or Low to observe SLG59H1009V operation.

Package Top Marking System Definition

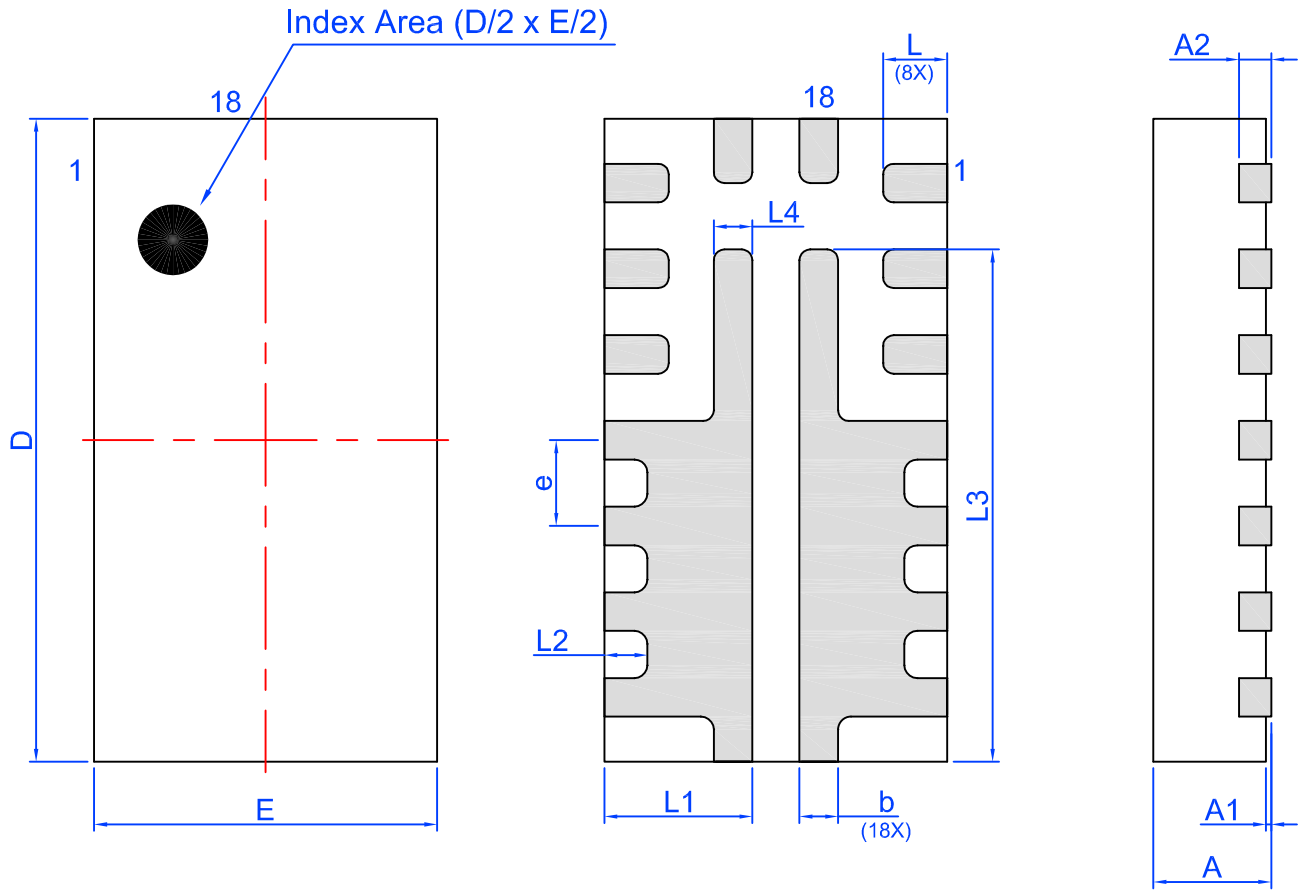


1009V - Part ID Field
WW - Date Code Field[1]
NNN - Lot Traceability Code Field[1]
A - Assembly Site Code Field [2]
RR - Part Revision Code Field[2]

Note 1: Each character in code field can be alphanumeric A-Z and 0-9
Note 2: Character in code field can be alphabetic A-Z

Package Drawing and Dimensions

18 Lead TQFN Package 1.6 x 3 mm (Fused Lead)
JEDEC MO-220, Variation WCEE

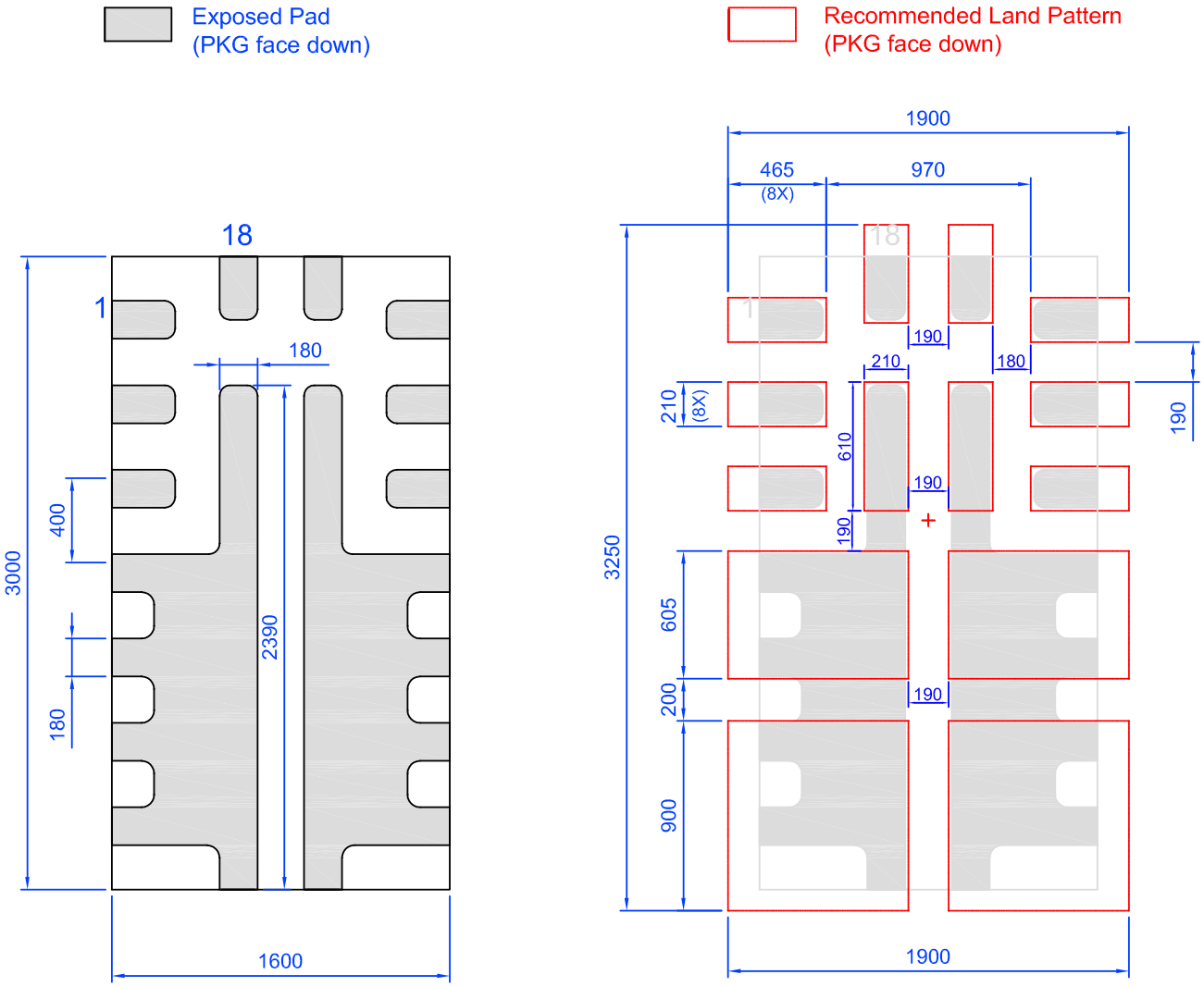


Top View BTM View Side View

Unit: mm

Symbol	Min	Nom.	Max	Symbol	Min	Nom.	Max
A	0.50	0.55	0.60	D	2.95	3.00	3.05
A1	0.005	-	0.05	E	1.55	1.60	1.65
A2	0.10	0.15	0.20	L	0.25	0.30	0.35
b	0.13	0.18	0.23	L1	0.64	0.69	0.74
e	0.40 BSC			L2	0.15	0.20	0.25
L3	2.34	2.39	2.44	L4	0.13	0.18	0.23

SLG59H1009V 18-pin STQFN PCB Landing Pattern



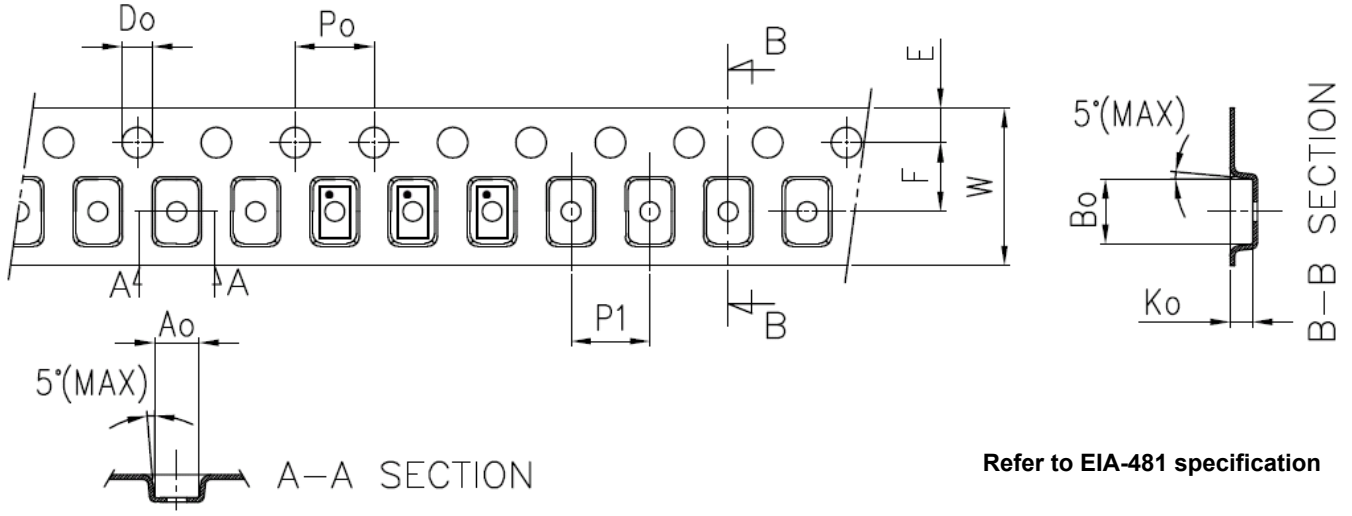
Note: All dimensions shown in micrometers (μm)

Tape and Reel Specifications

Package Type	# of Pins	Nominal Package Size [mm]	Max Units		Reel & Hub Size [mm]	Leader (min)		Trailer (min)		Tape Width [mm]	Part Pitch [mm]
			per Reel	per Box		Pockets	Length [mm]	Pockets	Length [mm]		
STQFN 18L 1.6x3mm 0.4P FC Green	18	1.6 x 3 x 0.55	3,000	3,000	178 / 60	100	400	100	400	8	4

Carrier Tape Drawing and Dimensions

Package Type	Pocket BTM Length	Pocket BTM Width	Pocket Depth	Index Hole Pitch	Pocket Pitch	Index Hole Diameter	Index Hole to Tape Edge	Index Hole to Pocket Center	Tape Width
	A0	B0	K0	P0	P1	D0	E	F	W
STQFN 18L 1.6x3mm 0.4P FC Green	1.78	3.18	0.76	4	4	1.5	1.75	3.5	8



Refer to EIA-481 specification

Recommended Reflow Soldering Profile

Please see IPC/JEDEC J-STD-020: latest revision for reflow profile based on package volume of 2.64 mm^3 (nominal). More information can be found at www.jedec.org.

Revision History

Date	Version	Change
12/12/2018	1.02	Updated style and formatting Updated Charts Added Scopeshots Added Layout Guidelines Fixed typos
10/26/2016	1.01	Updated General Description and Features
5/13/2016	1.00	Production Release

Mouser Electronics

Authorized Distributor

Click to View Pricing, Inventory, Delivery & Lifecycle Information:

Dialog Semiconductor:

SLG59H1009V