40V, 1000mΩ, Quad-Channel Smart High-Side Switch

1 FEATURES

- Automotive AEC-Q100 Grade 1 qualified
- Automotive AEC-Q100-012 Grade A qualified
- Wide V_{IN} Range: 4V to 40V
- Quad-Channel, 1000mΩ
- Individual EN Control for Each Channel
- Individual Diagnostics Output for Each Channel (Version A)
- Accuracy Current Sense (Version B)
- Adjustable Current Limit
- Robust Protection
  - Output Short to GND Protection
  - Over Current Protection
  - Thermal Shutdown
  - Inductive load Negative Voltage Clamp
- Full Diagnostics
  - Open Load Detection
  - Output Short to Battery Detection
  - Overcurrent and Output Short to GND Detection
- Operating Junction Temperature -40˚C to 150˚C
- Thermally Enhanced TSSOP-EP20

2 APPLICATIONS

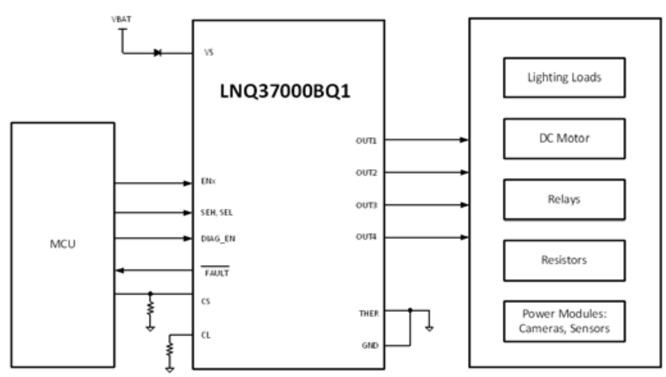
- Multichannel LED Drivers
- Multichannel High-Side Switches for Automotive Electronic Module
- Multichannel Relay, Solenoid Drivers
- General Resistance, Capacitance, and Inductance Load Switch
- General High-Side Switches for Power Module

3 DESCRIPTION

LNQ37000Q1 is a Quad-Channel smart high-side switch with four integrated 1000mΩ power MOSFETs. The device has full protection functions, including an external adjustable current limit, output short circuit protection, latching off or automatic restart over temperature protection and inductive load negative voltage clamp.

LNQ37000Q1 has full detection and diagnostics functions such as over current, output short to GND, open load, and output short to battery. LNQ37000AQ1 has individual diagnostics and fault report output for each channel. LNQ37000BQ1 has global fault report output for four channels, and it also integrated accurate current sense mirror to output the current information of the selected channel. With this current sense feature, the system can distinguish the specific fault channel by selecting SEL and SEH pin.

LNQ37000BQ1 Typical Application Diagram



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4 REVISION HISTORY

Version	Change Description	Date
1.0	Initial Version	2022/12/30

5 PRODUCT INFORMATION

Part Number	IC Package	MSL Peak-Temp (1)	Material	Package	Package Qty	Top Marking (2)
LNQ37000AQ1ALR	TSSOP-EP20	Level-3-260C	RoHS	Tape & Reel	3000	Q37000A
LNQ37000BQ1ALR	TSSOP-EP20	Level-3-260C	RoHS	Tape & Reel	3000	Q37000B

(1) MSL (Moisture Sensitivity Level) is based on JEDEC industrial classification, and the tabled temperature is the maximum solder temperature.

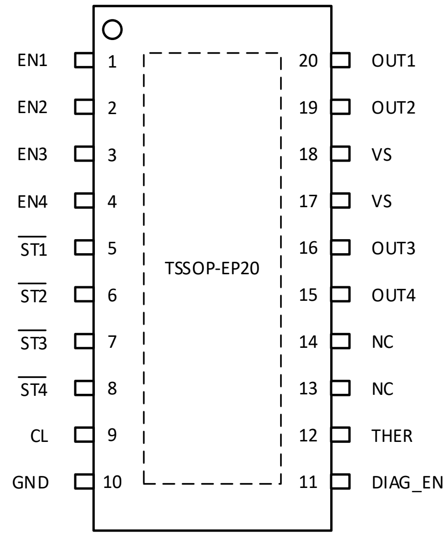
(2) There may be additional marking relates to the lot number or date code on the device.

6 PIN CONFIGURATION AND FUNCTION

6.1 Pin Configuration

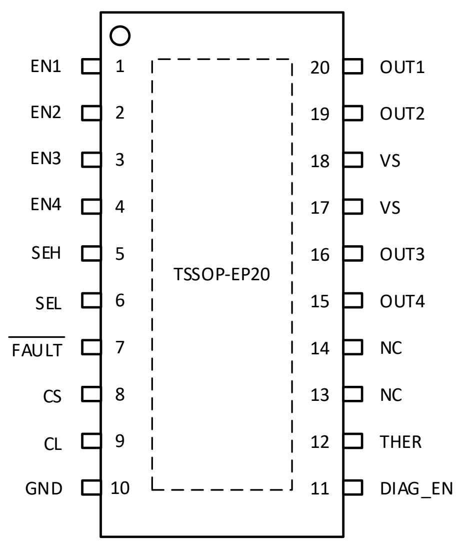
6.1.1 LNQ37000AQ1 Pin Configuration

LNQ37000AQ1 TSSOP-EP20 Top View



6.1.2 LNQ37000BQ1 Pin Configuration

LNQ37000BQ1 TSSOP-EP20 Top View



6.2 Pin Functions

Name	PIN Number		Type	Description
	LNQ37000 AQ1	LNQ37000 BQ1		
EN1	1	1	Signal	Enable pin for CH1, internal pulldown.
EN2	2	2	Signal	Enable pin for CH2, internal pulldown.
EN3	3	3	Signal	Enable pin for CH3, internal pulldown.
EN4	4	4	Signal	Enable pin for CH4, internal pulldown.
$\overline{ST1}$	5	-	Signal	Diagnostic output for CH1 (open drain), low level for fault.
$\overline{ST2}$	6	-	Signal	Diagnostic output for CH2 (open drain), low level for fault.
$\overline{ST3}$	7	-	Signal	Diagnostic output for CH3 (open drain), low level for fault.
$\overline{ST4}$	8	-	Signal	Diagnostic output for CH4 (open drain), low level for fault.
SEH	-	5	Signal	CS channel-selection high bit, internal pulldown.
SEL	-	6	Signal	CS channel-selection low bit, internal pulldown.
$\overline{FAULT}$	-	7	Signal	Global fault report (open drain), low level output for any channel fault.
CS	-	8	Signal	Current-sense output, sense channel is selected by SEL and SEH. Recommended to connect a capacitor ≥1nF to the ground.
CL	9	9	Signal	Connect a resistor to device GND to adjust current limit.
GND	10	10	Ground	Device GND
DIAG_EN	11	11	Signal	Enable pin for diagnostics, internal pulldown. High level to enable diagnostics function.
THER	12	12	Signal	Over temperature protection mode control, internal pulldown. Latch off when THER=H, auto restart when THER=L.
NC	13, 14	13, 14	-	No internal connection.
OUT4	15	15	Power	CH4 output.
OUT3	16	16	Power	CH3 output.
VS	17,18	17,18	Power	Power supply, connect a 4.7μF ceramic capacitor and a 0.1uF decoupling capacitor to GND is recommended.
OUT2	19	19	Power	CH2 output.
OUT1	20	20	Power	CH1 output.
Thermal Pad				Connect to device GND is recommended.

7 SPECIFICATIONS

7.1 Absolute Maximum Ratings (1)

Parameters	Min	Max	Unit
VS to GND	-0.3	42	V
ENx, $\overline{STx}$, CL, CS, SEH, SEL, DIAG_EN, $\overline{FAULT}$, THER to GND	-0.3	6	
Current on ENx, DIAG_EN, SEL, and THER pins(2)	-10	-	mA
Current on STx or FAULT pins(2)	-30	10	
Inductive load switch-off energy dissipation, single pulse, single channel (3)	-	23	mJ
Operating Ambient Temperature	-40	125	˚C
Junction Temperature	-40	150	
Storage Temperature	-55	150	

(1) Exceeding these absolute-maximum-ratings may damage the device.

(2) Value specified by design, not subject to production test.

(3) Test condition: V_{VS}=13.5V, L=300mH, T_J(initial)=150℃. Test on LNQ37000AQ1 EVM, FR4 4 layers board, 2×70μm Cu, 2×17.5μm Cu, 250mm^2 thermal pad copper area.

7.2 ESD Ratings

Parameters	Min	Max	Unit
HBM Human Body Model		±4000	V
CDM Charge Device Model		±750	

7.3 Recommended Operating Condition

Parameters	Min	Max	Unit
VS	4	40	V
ENx, $\overline{STx}$, CL, CS, SEH, SEL, DIAG_EN, $\overline{FAULT}$, THER	0	5.5	
Nominal DC load current	0	0.75	A
Operating Ambient Temperature	-40	125	˚C
Junction Temperature	-40	150	˚C

7.4 Package Thermal Parameters

Parameter (1)		TSSOP-EP20	Units
$R_{\theta JA}$	Junction-to-Ambient Thermal Resistance	39.3	˚C/W
ψ_{JT}	Junction-to-Top Characterization Parameter	3	˚C/W

(1) Measurements are based on standard 2s2p PCB defined in JESD 51-7 2s2p， under no wind , 2W loss, and 25 ˚C ambient temperature.

7.5 Electrical Characteristics

Unless otherwise stated, the minimum and maximum limits apply over the input voltage range of 4V≤VS≤40V, operating junction temperature range of -40˚C- 150˚C Typical values are measured at 25˚C and represent the most likely norm. The default conditions apply: $I_{CL(ext\_set)}$ = 0.5A.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Supply						
V_{VS}	Operating Input Voltage Range		4		40	V
$V_{VS(UVR)}$	VCC UVLO rising		3.5	3.7	3.9	V
$V_{VS(UVF)}$	VCC UVLO falling		3.1	3.3	3.5	V
$V_{VS(UVH)}$	VCC UVLO hysteresis			0.4		V
I_Q	Normal operating Current	V_{ENx} = 5V, V_{DIAG_EN}= 0V, I_{OUTx}= 1mA, Current limit = 0.5A		2.45	3.5	mA
I_{off}	Standby Current	V_{ENx} = V_{OUTx}= V_{DIAG_EN}= V_{CS}= V_{CL}= THER=0V, T_J = 25 ˚C		3	8	µA
		V_{ENx} = V_{OUTx}= V_{DIAG_EN}= V_{CS}= V_{CL}= THER=0V, T_J = 125 ˚C		7	15	
$I_{off(diag)}$	Standby Current with diagnostic enabled	V_{DIAG_EN}=5V, V_{ENx} = V_{OUTx}= V_{CS}= V_{CL}= THER=0V, not in open-load mode		0.4	3	mA
$t_{off(deg)}$	Standby mode deglitch time	V_{VS} = 13.5V, EN from high to low, if deglitch time > t (off, deg), the device enters into standby mode.	9	12.5	16	ms
$I_{lkg(out)}$	Output leakage current in off-state	V_{DIAG_EN}=0V, V_{ENx} = V_{OUTx}= 0V			0.5	uA
Power Switch						
$R_{DS(on)}$	CH1 - CH4 On-state resistance	V_{VS} ≥ 4V, T_J = 25 ˚C		0.9		Ω
		V_{VS} ≥ 4V, T_J = 150 ˚C			2	Ω
$V_{DS(CLAMP)}$	V_{VS} to V_{OUTX} clamp voltage	V_{VS} = 13.5V	41	46	52	V
Reverse Diode Characteristics						
$V_{F-REVERSE}$	Dain-source diode voltage	V_{ENx} = 0V， I_{OUTx} = -0.15A	0.5	0.85	1.1	V
$I_{R(1)}$	Continuous reverse current from source to drain(1)	t<60s, V_{ENx} = 0V， T_J = 25 ˚C, output short to battery, single channel reversed		1		A
$I_{R(2)}$	Continuous reverse current from source to drain(1)	t<60s, V_{ENx} = 0V， GND pin is connected 1kohm resistor in parallel with diode. T_J = 25 ˚C, Reverse-polarity condition, all channels reversed		1		A

Electrical Characteristics (Continued)

Current Limit						
$V_{CL(th)}$	External current limit threshold			0.8		V
$I_{CL(ext)}$	External current limit threshold for CH1 - CH4	R_{CL}= 220ohm, 4V≤V_{VS} -V_{OUTx}≤16V		1	1.6	A
		R_{CL}=220ohm, 16V < V_{VS} -V_{OUTx} ≤ 40V[1]		0.5	0.8	A
K_{CL}	External current limit gain	0.1A ≤$I_{CL(ext\_set)}$ < 0.5A		270		
		0.5A ≤$I_{CL(ext\_set)}$ ≤ 0.9A		280		
$\Delta K_{CL}/ K_{CL}$	Current limit accuracy[2], (IOUTx – I_{CL} ×K_{CL}) × 100/ (I_{CL} ×K_{CL})	V_{VS} = 13.5V, $I_{CL(ext\_set)}$ ≥ 100 mA	-70		70	%
		V_{VS} = 13.5V, $I_{CL(ext\_set)}$ ≥ 200 mA	-45		45	%
		V_{VS} = 13.5V, 0.5A ≤ $I_{CL(ext\_set)}$ ≤ 0.9A	-24		24	%
Current Sense (LNQ37000BQ1)						
K_{CS}	Current-sense ratio			80		
$\Delta K_{CS}/ K_{CS}$	Current-sense accuracy, (I_{CS} ×K_{CS} – IOUTx) × 100 /IOUTx	V_{VS} = 13.5 V, IOUTx ≥ 5 mA	-42		42	%
		V_{VS} = 13.5 V, IOUTx ≥ 25 mA	-15		15	%
		V_{VS} = 13.5 V, IOUTx ≥ 100 mA	-8		8	%
$V_{CS(lin)}$	Linear current-sense voltage range[1]	V_{VS} ≥ 6.5 V	0		3.5	V
		5 V ≤ V_{VS} < 6.5 V	0		V_{VS}-2.5	V
$I_{OUTx(lin)}$	Output-current linear range[1]	V_{VS} ≥ 6.5V, $V_{CS(lin)}$ ≤ 3.5 V	0		0.75	A
		5 V ≤ V_{VS} < 6.5 V, $V_{CS(lin)}$ ≤ V_{VS} – 2.5 V	0		0.5	A
$V_{CS(H)}$	Fault current sense voltage range[1]	V_{VS} ≥ 7 V, fault mode	4.3		5.5	V
		5 V ≤ V_{VS} < 7 V, fault mode	V_{VS}-2		5.5	V
$I_{CS(H)}$	Current-sense pin output current	V_{VS} = 13.5 V, fault mode	11	20	34	mA
$I_{lkg(CS)}$	Current-sense leakage current in disabled mode	V_{VS} = 13.5 V, V_{DIAG_EN} = 0 V			0.5	uA
Diagnostics						
$V_{OL(th)}$	Open load detection threshold	V_{VS} = 13.5 V	1.6	2	2.4	V
$V_{OL(hys)}$	Open load detection threshold hysteresis	V_{VS} = 13.5 V		0.2		V
$t_{CL(deg)}$	Deglitch time from current limit occurred to $\overline{STx}/\overline{FAULT}$	V_{VS} = 13.5 V, I_{OUTx}=0.5A	60	120	220	µs
$t_{OL(deg)}$	Open load detection threshold deglitch time	V_{VS} = 13.5 V	400	600	800	µs
$I_{OL(off)}$	Off-state output sink current	V_{VS} = V_{OUTx} =13.5V, V_{ENx} = 0V, V_{DIAG_EN}= 5V, open load	-75			µA
$I_{lkg(out)\_diag}$	Off-state output leakage current with diagnostics	V_{OUTx} =0V, V_{ENx} = 0V, V_{DIAG_EN}= 5V			200	µA

Electrical Characteristics (Continued)

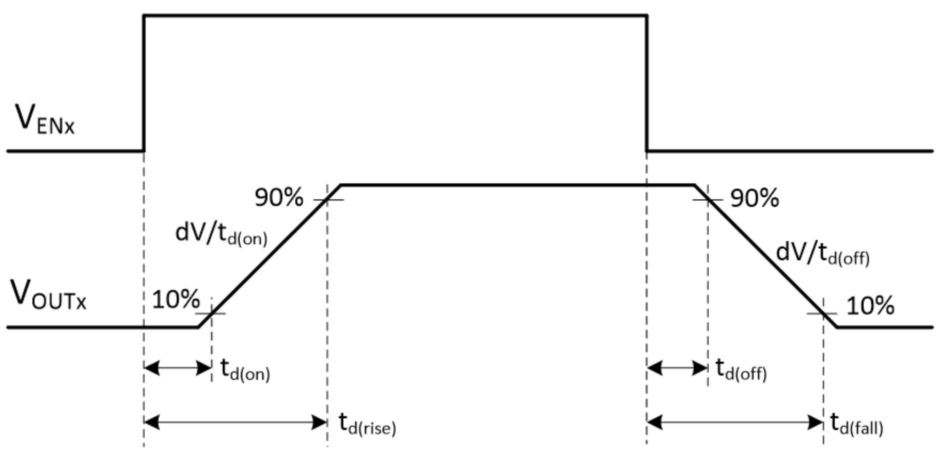
Logic Inputs (ENx, SEH, SEL, DIAG_EN, THER)						
V_{IH}	Input logic high voltage		2			V
V_{IL}	Input logic low voltage				0.8	V
$R_{(logic,pd)}$	ENx, SEH, SEL, THER Logic-pin pull down resistor	V_{VS} =13.5V, V_{ENx} =V_{SEH}= V_{SEL}= V_{THER}= 3.3V	125	200	275	kΩ
	DIAG_EN, Logic-pin pull down resistor	V_{VS} =13.5V, V_{DIAG_EN} = 3.3V	200	300	400	
Logic Outputs ($\overline{STx}$, $\overline{FAULT}$)						
$V_{OL(STx)}$	Status pin low-output voltage	I_{STx} = 2 mA, LNQ37000AQ1 only			0.2	V
$V_{OL(FAULT)}$	$\overline{FAULT}$ pin low-output voltage	I_{FAULT} = 2 mA, LNQ37000BQ1 only			0.2	V
Thermal Shutdown						
$T_{(sd)}$ (1)	Thermal shutdown threshold			170		˚C
$T_{(sd\_hys)}$ (1)	Hysteresis for thermal shutdown			20		˚C
$T_{(sw)}$ (1)	Thermal swing shutdown threshold			45		˚C
$T_{(sw\_hys)}$ (1)	Hysteresis for thermal swing			15		˚C
Switching Characteristics						
$t_{d(on)}$	Turn on delay, ENx rising edge to 10% of V_{OUTx}	V_{VS} =13.5V, V_{ENx} =5V, I_{OUTx}=0.1A, current limit=0.5A	7	15	30	µs
$t_{d(off)}$	Turn off delay, ENx falling edge to 90% of V_{OUTx}	V_{VS} =13.5V, V_{ENx} =5V, I_{OUTx}=0.1A, current limit=0.5A	2	30	60	µs
$dV/dt_{d(on)}$	Turn on slew rate, V_{OUTx} from 10% to 90%	V_{VS} =13.5V, V_{ENx} =5V, I_{OUTx}=0.1A, current limit=0.5A	0.1	0.3	0.5	V/µs
$dV/dt_{d(off)}$	Turn off slew rate, V_{OUTx} from 90% to 10%	V_{VS} =13.5V, V_{ENx} =5V, I_{OUTx}=0.1A, current limit=0.5A	0.3	0.8	4	V/µs
$t_{d(match)}$	$t_{d(rise)} - t_{d(fall)}$,$t_{d(rise)}$, ENx rising edge to 90% of V_{OUTx} ,$t_{d(fall)}$, ENx falling edge to 10% of V_{OUTx}	V_{VS} =13.5V, V_{ENx} =5V, I_{OUT}=0.1A, current limit=0.5A	-25	3	60	µs

Electrical Characteristics (Continued)

Current Sense Characteristics						
$t_{cs(on1)}$	CS settling time from DIAG_EN enabled , DIAG_EN rising edge to 90% of V_{CS}	V_{VS} =13.5V, V_{ENx} =5V, I_{OUT}=0.1A, current limit=0.5A			5	µs
$t_{cs(off1)}$	CS settling time from DIAG_EN disabled, DIAG_EN falling edge to 10% of V_{CS}	V_{VS} =13.5V, V_{ENx} =5V, I_{OUT}=0.1A, current limit=0.5A			5	µs
$t_{cs(on2)}$	CS settling time from EN rising edge, EN rising edge to 90% of V_{CS}	V_{VS} =13.5V, V_{DIAG_ENx} =5V, I_{OUT}=0.1A, current limit=0.5A	80	210	330	µs
$t_{cs(off2)}$	CS settling time from EN falling edge, EN falling edge to 10% of V_{CS}	V_{VS} =13.5V, V_{DIAG_ENx} =5V, I_{OUT}=0.1A, current limit=0.5A			5	µs
t_{sel}	Multi-sense transition delay from channel to channel	V_{VS} =13.5V, V_{DIAG_EN} = 5 V, current sense output delay when multi-sense pin SEL transitions from channel to channel			5	µs

(1) Value specified by design, not subject to production test.

(2) Current limit accuracy is only applicable to overload condition at VDS≥3.5V.

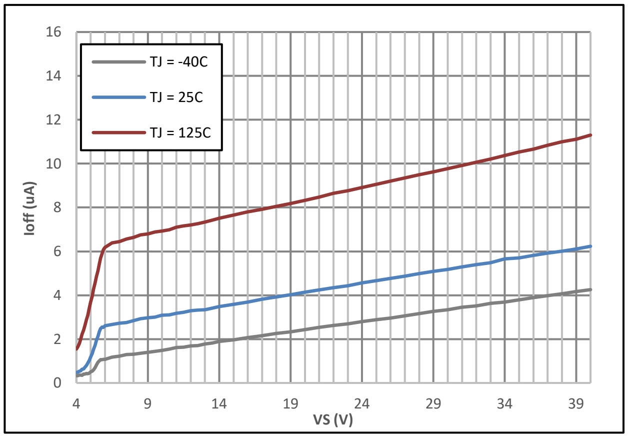


Switching Characteristics Diagram

7.6 Typical Characteristics

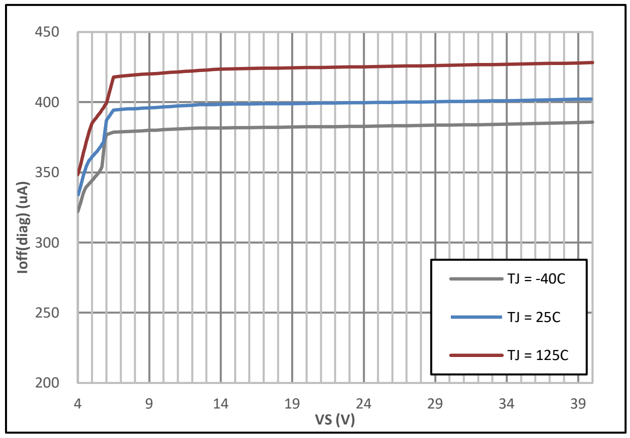
7.6.1 Parameter Curves

Unless otherwise stated, the test conditions are: V_{VS} = 13.5V, R_{CL} = 442ohm, TA = 25˚C.



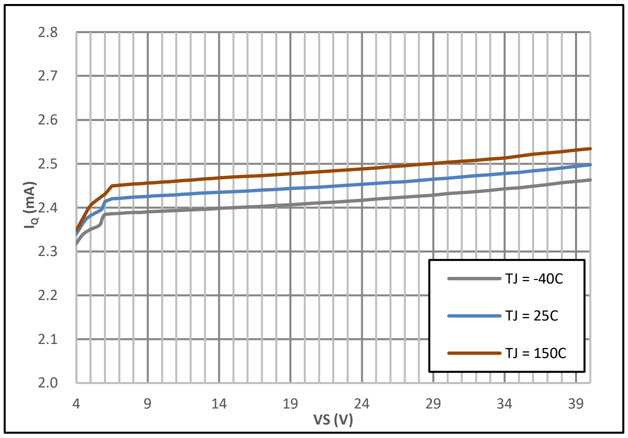
EN = DIAG_EN = 0V

Figure 1. Ioff



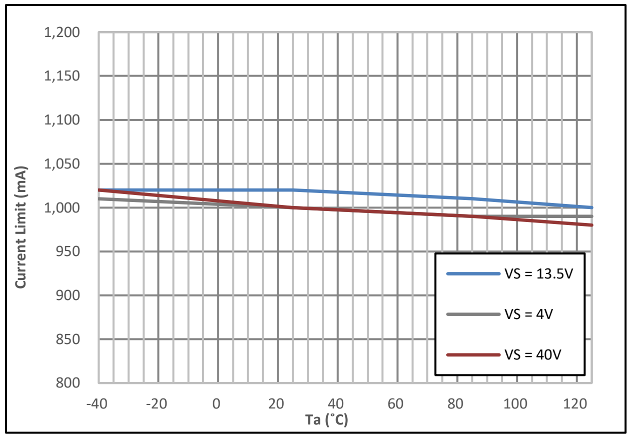
EN = 0V, DIAG_EN = 5V

Figure 2. Ioff(diag)



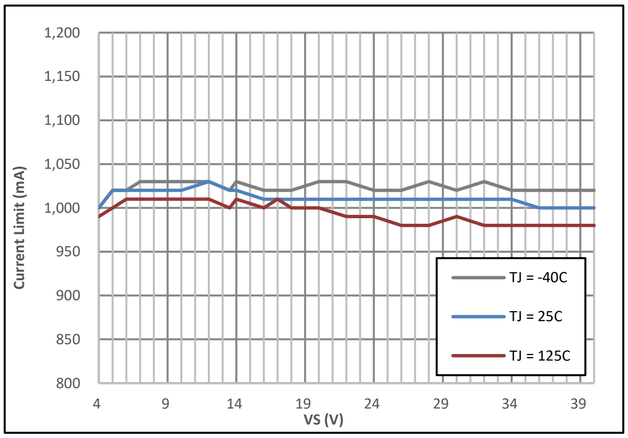
EN = DIAG_EN = 5V

Figure 3. I_Q



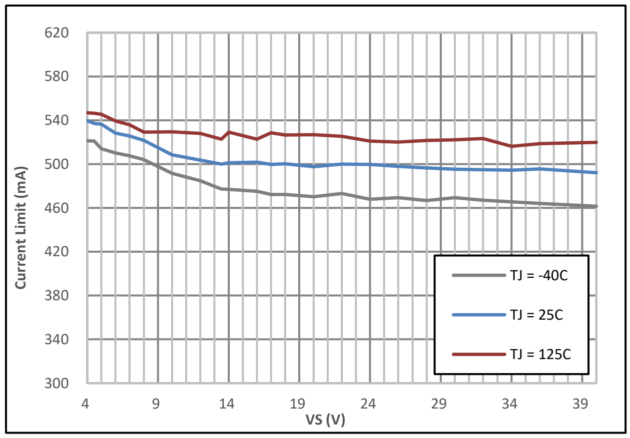
RCL = 220ohm, VDS = 3.5V

Figure 4. Current Limit vs. Temperature



RCL=220ohm, VDS=3.5V

Figure 5. Current Limit vs. Supply Voltage

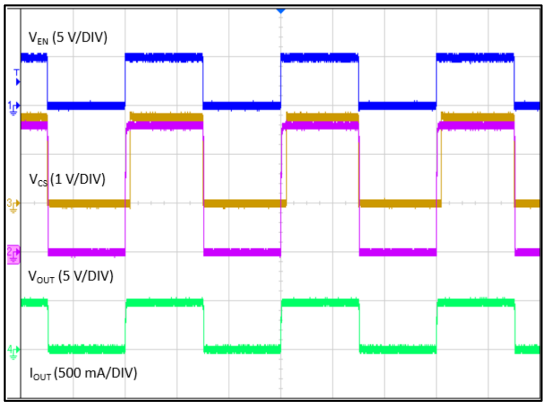


RCL=442ohm, VDS=3.5V

Figure 6. Current Limit vs. Supply Voltage

7.6.2 Typical Waveforms

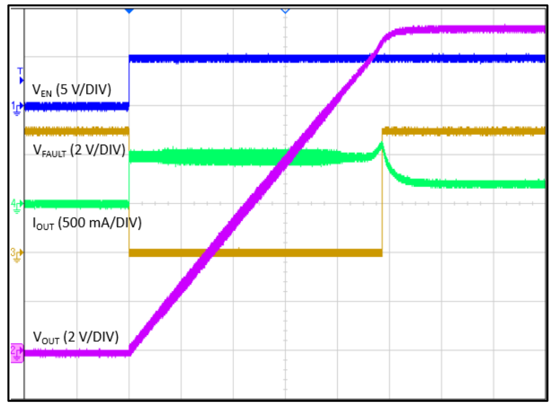
Unless otherwise stated, the test conditions are: V_{VS} = 13.5V, R_{CL} = 442ohm, TA = 25˚C.



Time (2 ms/DIV)

V_{VS} = 13.5V, LOAD = 0.5A, R_{CS} = 300ohm

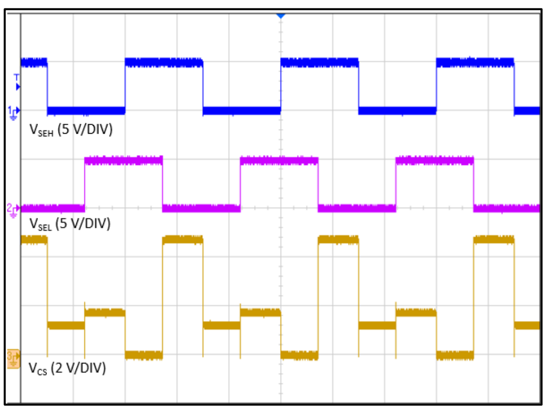
Figure 7. LNQ37000BQ1, Startup/Shutdown through EN



Time (20 ms/DIV)

V_{VS} = 13.5V, C_{LOAD} = 2.3mF, I_{OUT} = 0.2A, R_{CL} = 442ohm

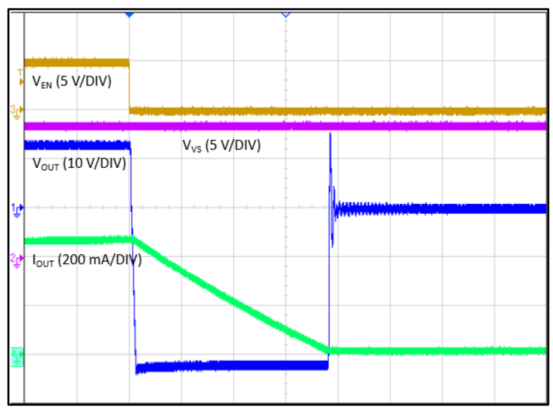
Figure 8. LNQ37000BQ1, Startup with Capacitive Load



Time (2 ms/DIV)

V_{VS} = 13.5V, R_{CS} = 300ohm, I_{OUT1} = 0.2A, I_{OUT2} = 0.5A, I_{OUT3} Overload, I_{OUT4} = 0A

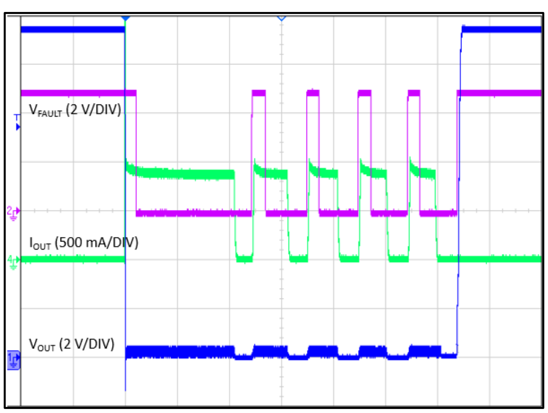
Figure 9. LNQ37000BQ1, Current Sense Channel Transition



Time (1 ms/DIV)

V_{VS} = 13.5V, L_{LOAD} = 300mH, R_{LOAD} = 27ohm

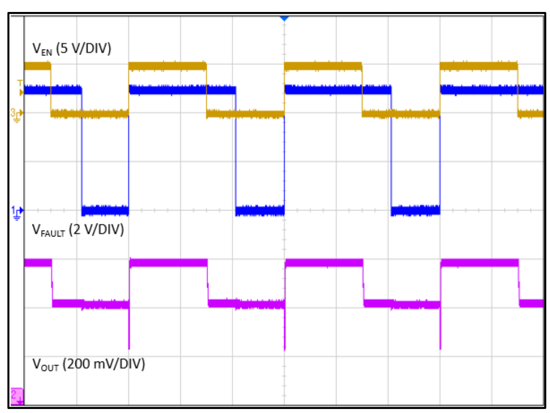
Figure 10. LNQ37000BQ1, VDS Clamp



Time (500 us/DIV)

V_{VS} = 13.5V, R_{CL} = 220ohm

Figure 11. LNQ37000BQ1, Short Protection



Time (1 ms/DIV)

V_{VS} = 13.5V, Connect 20kohm Resistor from OUT to VS

Figure 12. LNQ37000BQ1, Open Load Detection

8 FUNCTIONAL BLOCK DIAGRAM

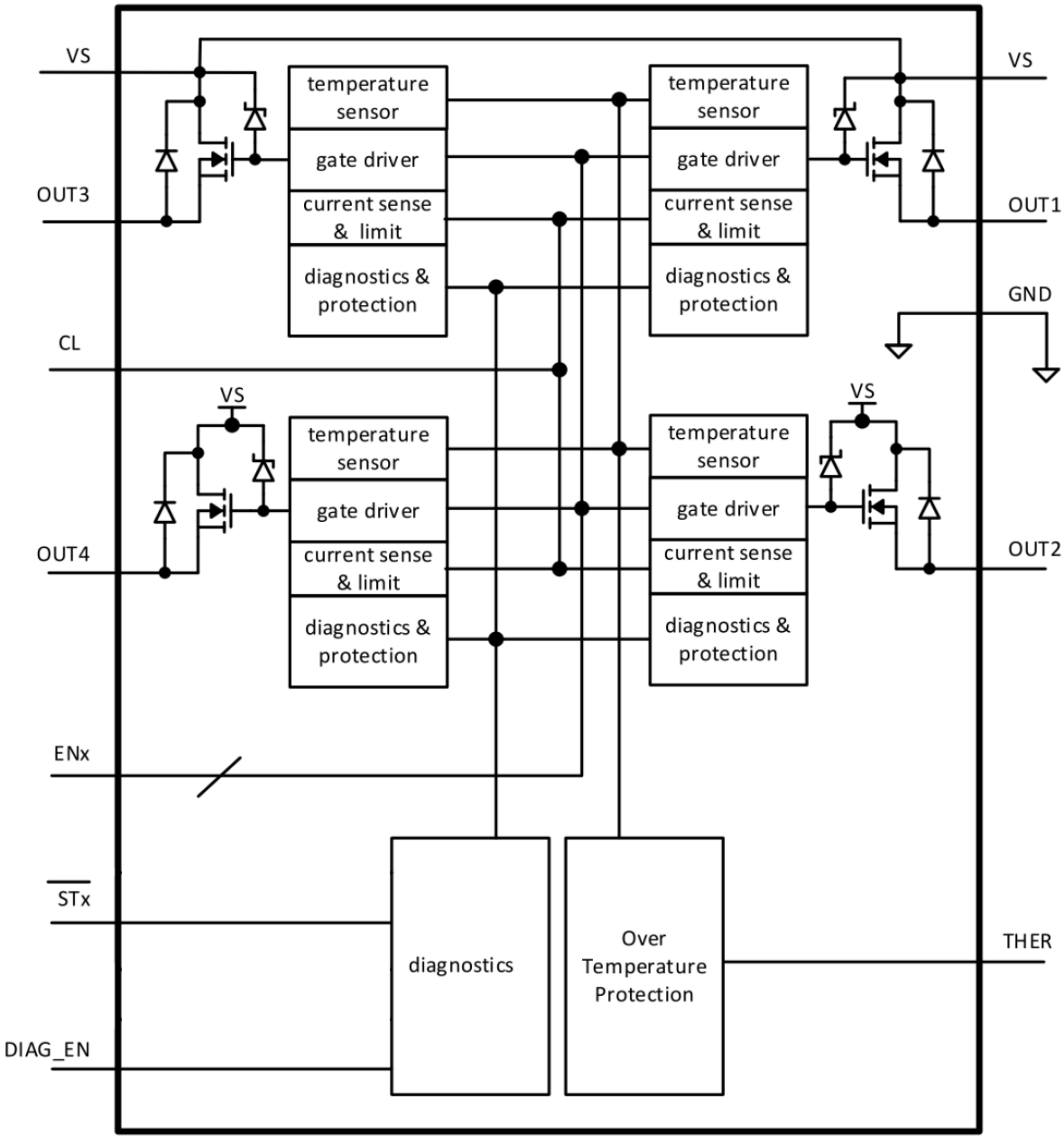


Figure 13. LNQ37000AQ1 Functional Block Diagram

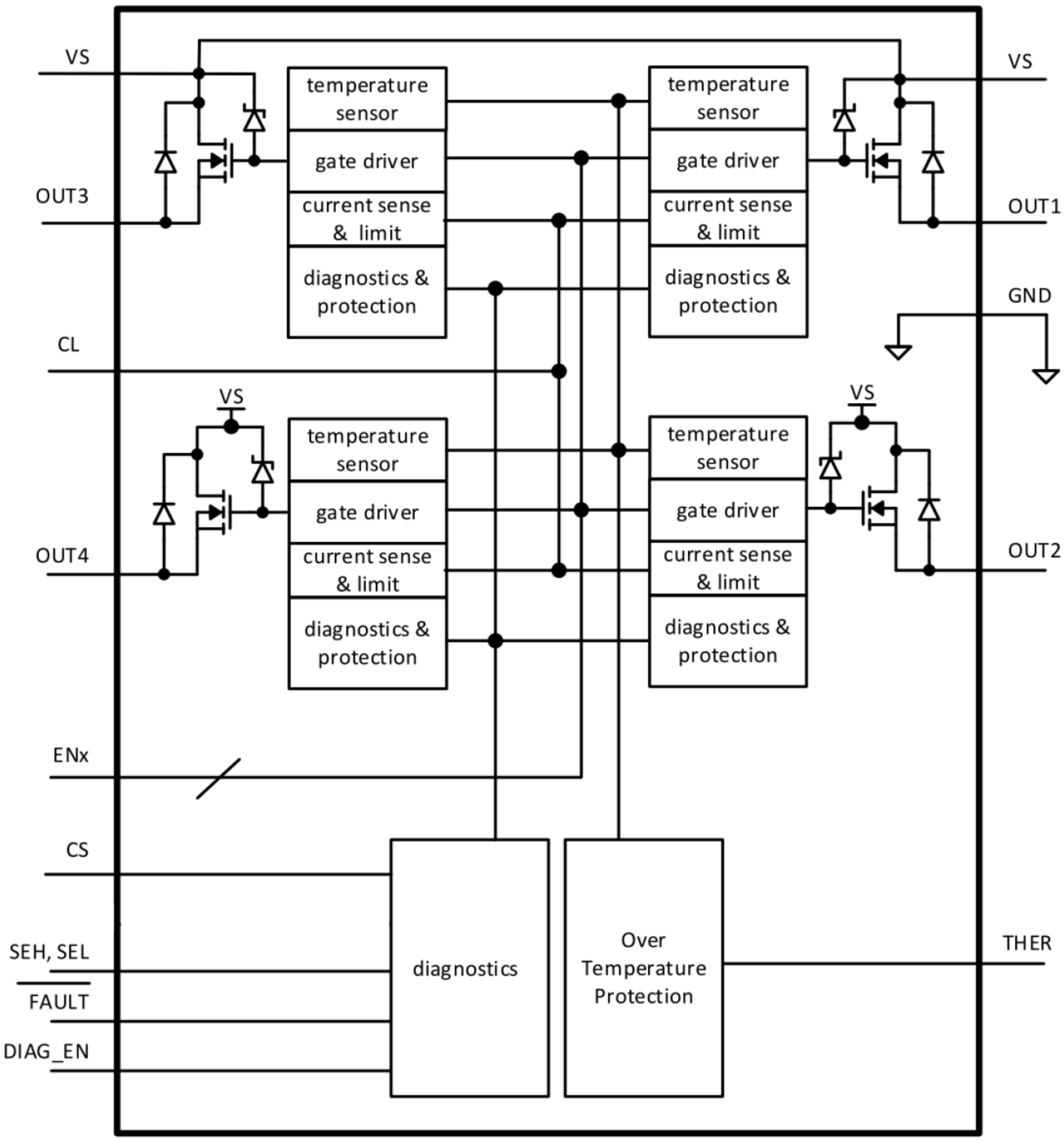


Figure 14. LNQ37000BQ1 Functional Block Diagram

9 FUNCTION DESCRIPTION

LNQ37000Q1 is a Quad-Channel smart high-side switch with four integrated 1000mΩ power MOSFETs. The device has full protection functions, including an external adjustable current limit, output short circuit protection, latching off or automatic restart over temperature protection and inductive load negative voltage clamp.

LNQ37000Q1 has full detection and diagnostics functions such as over current, output short to GND, open load, and output short to battery. LNQ37000AQ1 has individual diagnostics and fault report output for each channel. LNQ37000BQ1 has global fault report output for four channels, and it also integrated accurate current sense mirror to output the current information of the selected channel. With this current sense feature, the system can distinguish the specific fault channel by selecting SEL and SEH pin. LNQ37000Q1 is packaged with thermally enhanced TSSOP-EP20.

9.1 Working Mode

LNQ37000Q1 will start up when VS power up and V_{VS} is higher than the rising UVLO threshold. After startup initialization, the device enters standby state. At this time, if changing the state of EN or DIAG_ EN, the device will enter normal operation state or standby mode with diagnostic function. The working process is shown in the figure below.

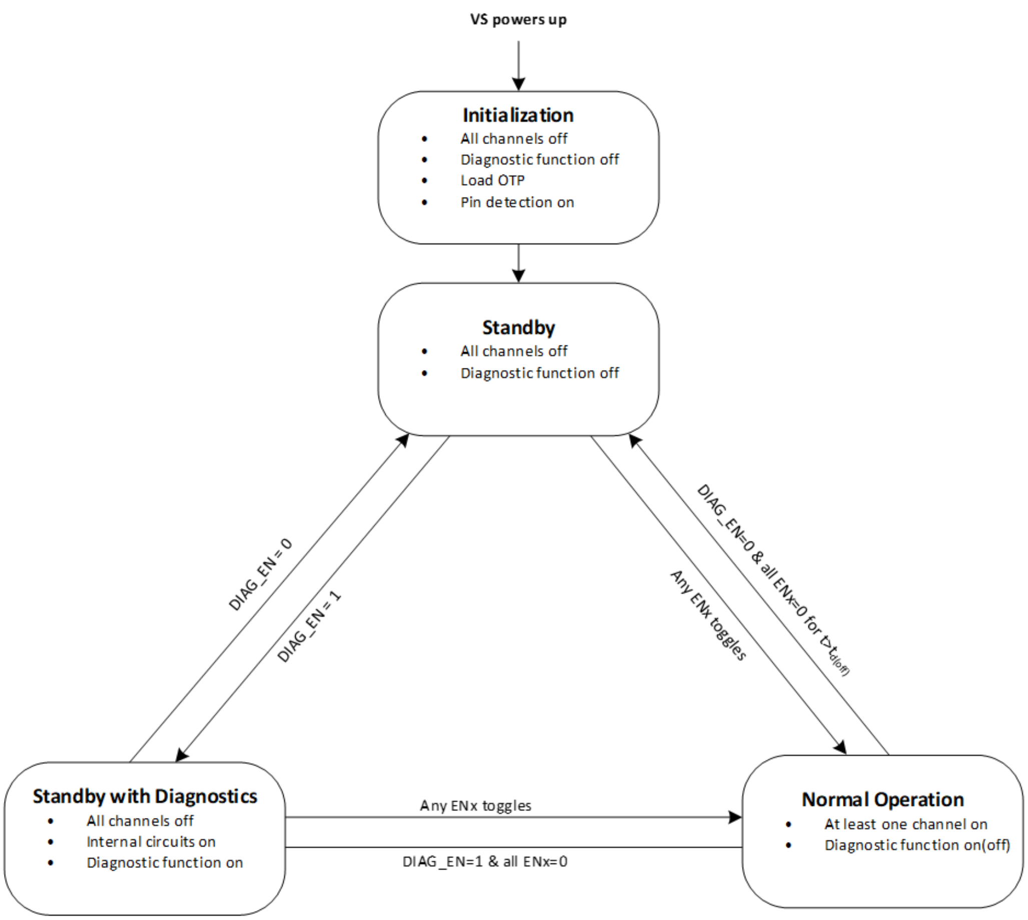


Figure 15. Working Mode Diagram

9.2 Input and Output

9.2.1 Power Supply - VS

VS is the power input for four channels. It is recommended to connect a 4.7μF ceramic capacitor and a 0.1uf decoupling capacitor to GND.

9.2.2 Channel Output - OUTx

OUTx are channel output pin. For the channels not used, a resistor should be connected between OUTx and GND. Recommended resistor value is ≤10kohm.

9.2.3 Enable Control - ENx

ENx are enable control pins for each channel. When EN voltage level is higher than 2V, the corresponding channel can be turned on. When EN voltage level is lower than 0.8V, the corresponding channel can be shut down.

9.2.4 Input UVLO Protection

When V_{VS} is higher than the UVLO rising threshold, the device starts up and enter standby or normal operating mode. When V_{VS} is lower than the UVLO falling threshold, the device shuts down.

9.3 Adjustable Current Limit

LNQ37000Q1 has adjustable current limit, a current limit resistor R_{CL} is connected between CL and GND to adjust the threshold of output current. The set value is determined by the following equation:

$$I_{CL(ext,set)} = \frac{V_{CL(th)} * K_{CL}}{R_{CL}}$$

$V_{CL(th)}$ is internal reference voltage, K_{CL} is the ratio of the output current to the current in resistor R_{CL}. When 4V<V_{VS}≤ 16V, the output current is limited to the set value if over current occurred. When V_{VS} -V_{OUTx} >16V and the set current limit is higher than 0.5A, the output current will be limited to 0.5A but not the set value. The sectional current limit function is shown as below diagram:

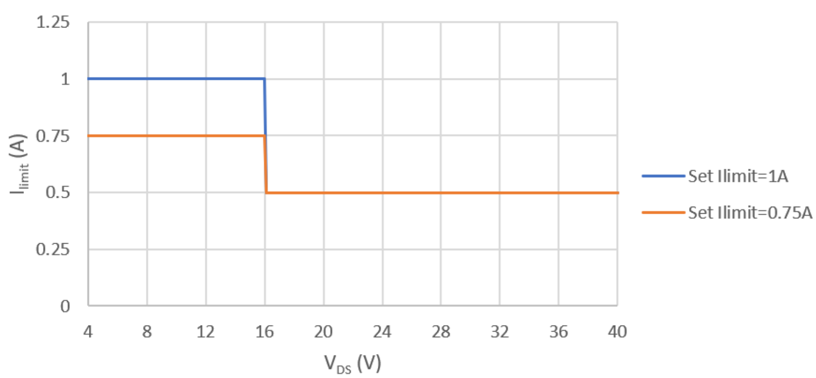


Figure 16. Sectional Current Limit

9.4 Current Sense (LNQ37000BQ1 Only)

9.4.1 Current Sense Channel-selection - SEH and SEL

The current sense channel is selected by SEH and SEL for LNQ37000BQ1. The output current is reduced proportionally and output by CS pin for the selected channel.

SEH	SEL	CHANNEL
L	L	1
L	H	2
H	L	3
H	H	4

9.4.2 Accurate Current Sense

LNQ37000BQ1 CS pin outputs a mirror current proportional to the output current of the selected channel. The current sense proportionality is K_{CS}.

$$K_{CS} = \frac{I_{OUTx}}{I_{CS}}$$

A sense resistor is connected between CS and GND, the sense current flow through the sense resistor and the sense voltage V_{CS} is measured by MCU. The value of sense resistor should meet following formula, and the maximum value of $V_{CS(NORMAL)}$ should also be lower than the full scale of MCU ADC.

$$V_{CS(NORMAL)} = I_{CS} * R_{CS} < MAX(V_{CS(lin)})$$

When a fault occurs, a fault voltage $V_{CS(FAULT)}$ is output at CS pin. $V_{CS(FAULT)}$ is the smaller value of $I_{CS(H)} * R_{CS}$ and $V_{CS(H)}$, as shown in the following formula:

$$V_{CS(FAULT)} = \mathrm{MIN}[I_{CS(H)} * R_{CS}, V_{CS(H)}]$$

It is recommended to connect a capacitor no less than 1nF to suppress interference.

9.5 Robust Protection Fuction

9.5.1 Output Short to GND and Over Load Protection

When a short to GND or overload condition occurs, the output current is clamped at the set current limit value, protects the load and the power supply from overstressing. An external resistor is used to set the current limit threshold. The details can refer to section 9.3. The device automatically recovers when the over current condition is removed.

9.5.2 Over Temperature Protection

There are two over temperature protection behaviors, one is thermal swing, the other is thermal shut down. There are four temperature sensors $T_{(FETx)}$ close to the power MOSFET of each channel, and a temperature sensor $T_{(logic)}$ close to the logic circuit. Each channel has individual over temperature protection.

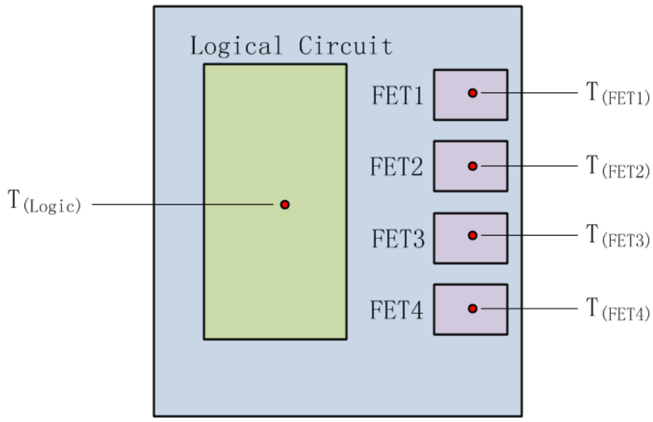


Figure 17. Temperature Sensor

- **Thermal swing.**

When $T_{(FETx)}$ is increasing sharply and $T_{(FETx)}$ - $T_{(logic)}$ > $T_{(sw)}$, thermal swing activates, then output is turned off shortly. When $T_{(FETx)}$ - $T_{(logic)}$ < $T_{(sw)}$ - $T_{(sw\_hys)}$, the output automatically recovers. Thermal swing responses rapidly when fast thermal variation occurs, thus prevent chip damage due to excessive local temperature rise.

- **Thermal shut down.**

When $T_{(FETx)}$ is higher than the absolute temperature, that is $T_{(FETx)}$ > $T_{(sd)}$, thermal shut down activates. There are two protection mode according to the configuration of THER pin. THER=L, channel output is turned off and automatically recovers when $T_{(FETx)}$ < $T_{(sd)}$ -$T_{(sd,hys)}$. THER=H, channel output is latched off and will not restart, unless the related ENx pin is toggled and $T_{(FETx)}$ < $T_{(sd)}$ -$T_{(sd,hys)}$.

9.5.3 Inductive-Load Switching-Off Clamp

When switching off an inductive load, negative voltage will be generated across the inductor, so the output of the switch pulled to negative. If no special control of the negative voltage, the power MOSFET may got damaged . LNQ37000Q1 integrated an internal clamp circuit to limit the negative voltage to $V_{DS(CLAMP)}$ and protect the power MOSFET from damage.

$$V_{DS(CLAMP)} = V_{VS} - V_{OUT}$$

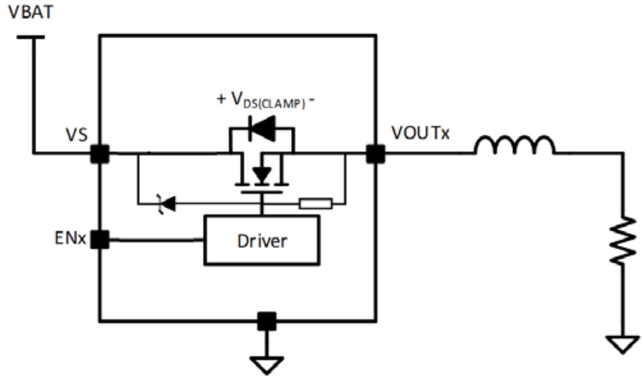


Figure 18. VDS_CLAMP Circuit

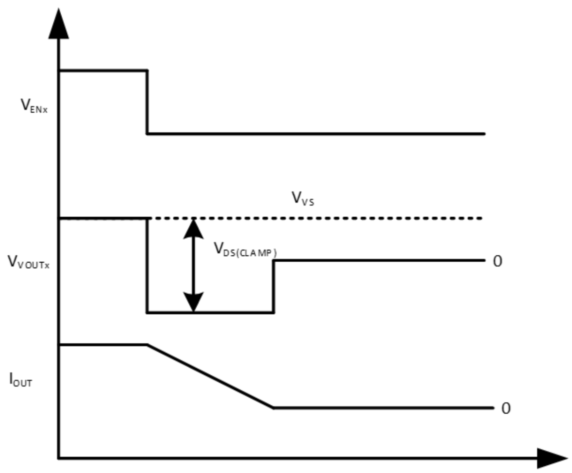


Figure 19. Inductive Load Switching off Diagram

Note that for PWM-controlled inductive loads, the negative voltage stress is repetitive. An external free-wheeling circuit is recommended to protect the device. The circuit is shown in the figure below:

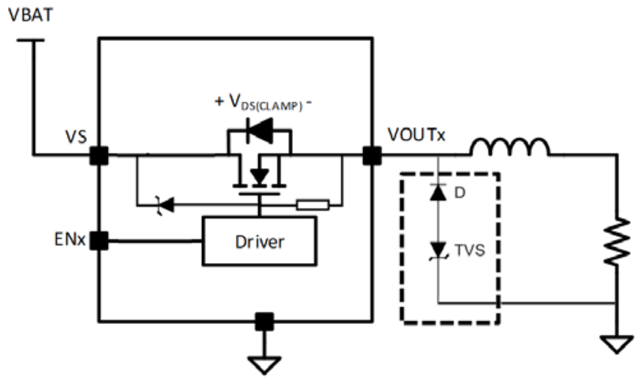


Figure 20. Protection with External Circuit

9.6 Diagnostics and Fault

9.6.1 Diagnostics and Fault Enable - DIAG_EN

DIAG_EN can enable and disable diagnostics and fault function to save power consumption. When DIAG_EN is high, diagnostics and fault function is enabled. When DIAG_EN is low, diagnostics and fault function is disabled, and CS, $\overline{\mathrm{STx}}$ or $\overline{\mathrm{FAULT}}$ are in high impedance output state to save the quiescent current.

9.6.2 Diagnostics and Fault Output - $\overline{\mathrm{STx}}/\overline{\mathrm{FAULT}}$

LNQ37000AQ1 has individual diagnostics and fault output for each channel. When one of the channels has fault, the corresponding $\overline{\mathrm{ST}}$ pin changes to low level to indicate fault state. LNQ37000BQ1 has global diagnostics and fault output for four channels. When any channel has fault, $\overline{\mathrm{FAULT}}$ pin will change to low level to indicate fault state. $\overline{\mathrm{STx}}/\overline{\mathrm{FAULT}}$ are open drain output, an external pull up resistor connected to 3.3V or 5V is necessary.

Diagnostics and fault configuration table is as below:

Conditions	ENx	OUTx	$\overline{\mathrm{STx}}$/ $\overline{\mathrm{FAULT}}$/	CS	THER	Fault Recovery
UVLO	-	L	H	0V	-	-
Normal	L	L	H	0V	-	-
	H	H	H	Linear Voltage	-	-
Overload, short to ground	H	L	L	$V_{CS(FAULT)}$	-	Auto
Open load(1)	L	H	L	$V_{CS(FAULT)}$	-	Auto
Short to battery	L	H	L	-	-	Auto
Thermal shutdown	H	L	L	$V_{CS(FAULT)}$	L	Auto recovery when $T_j < T_{(sd)} - T_{(sd\_hys)}$
					H	Latch off and restart when ENx toggle& $T_j < T_{(sd)} - T_{(sd\_hys)}$
Thermal swing	H	L	L	$V_{CS(FAULT)}$	-	Auto

(1) An external pullup is required for open-load detection.

9.6.3 Short-to-GND and Overload Detection

A short to GND or overload condition causes overcurrent, If the overcurrent triggers the current-limit threshold, the fault is reported out. When the microcontroller gets the fault report, it can handle the overcurrent by turning off the switch. When the overcurrent disappears, the fault report is removed automatically.

9.6.4 Open Load Detection

When DIAG_EN is high level and ENx is low level, open load detection is enabled. A 20kohm detection resistor R_{OL} is recommended between VS and OUTx to achieve this function. There is a leakage current $I_{OL(off)}$ flow through the output and GND due to internal logic circuit. When ENx is low level, the channel turns off. If a load is connected, OUTx is pulled down to GND. But if no load is connected, $I_{OL(off)}$ flowing through the detection resistor to internal GND, so OUTx is pulled up close to VS voltage, the voltage drop on detection resistor is determined by following equation:

$$V_{VS} - V_{OUTx} = R_{OL} * I_{OL(off)}$$

When the voltage drop meet below formula, the open load fault is reported out.

$$V_{VS} - V_{OUTx} < V_{OL(th)}$$

9.6.5 Short to Battery Detection

Output short to battery has the same detection mechanism as open-load detection. When DIAG_EN is high level and ENx is low level, if output short to battery, OUTx is equal to or over than VS voltage, $\overline{\mathrm{STx}}/\overline{\mathrm{FAULT}}$ will report fault. Note that when short to battery occurs, the reverse current must be no more than $I_{R(1)}$, otherwise the device may be damaged.

10 APPLICATION INFORMATON

10.1 Typical Application for LNQ37000AQ1

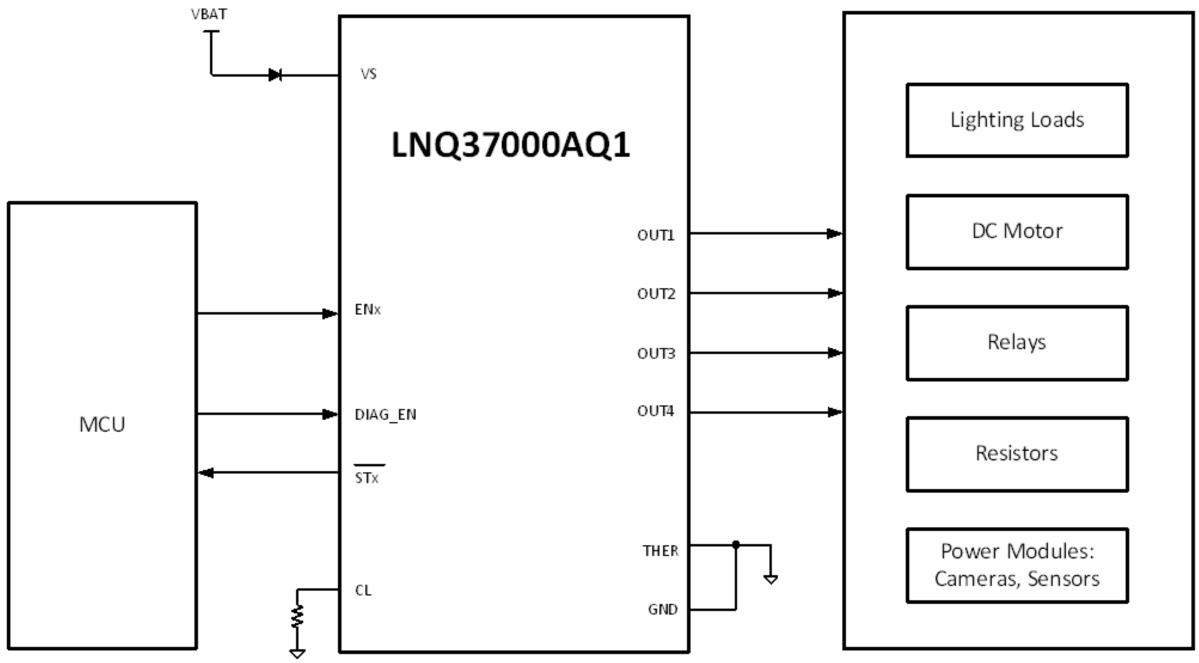


Figure 21. Typical Application for LNQ37000AQ1

10.2 Typical Application for LNQ37000BQ1

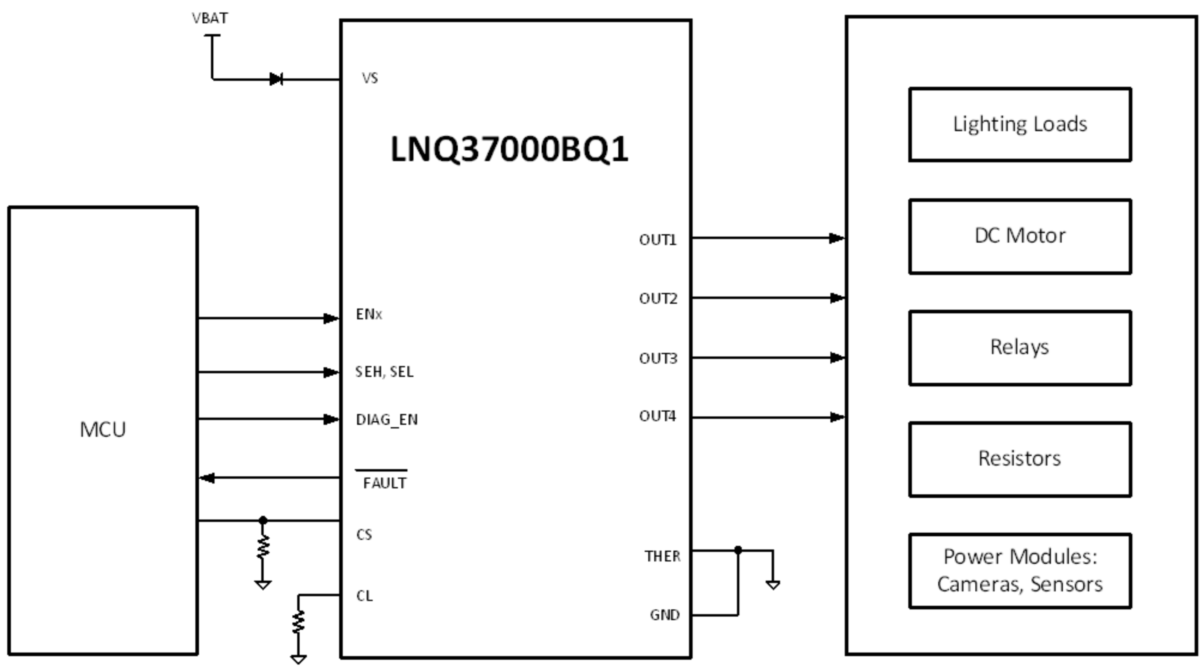
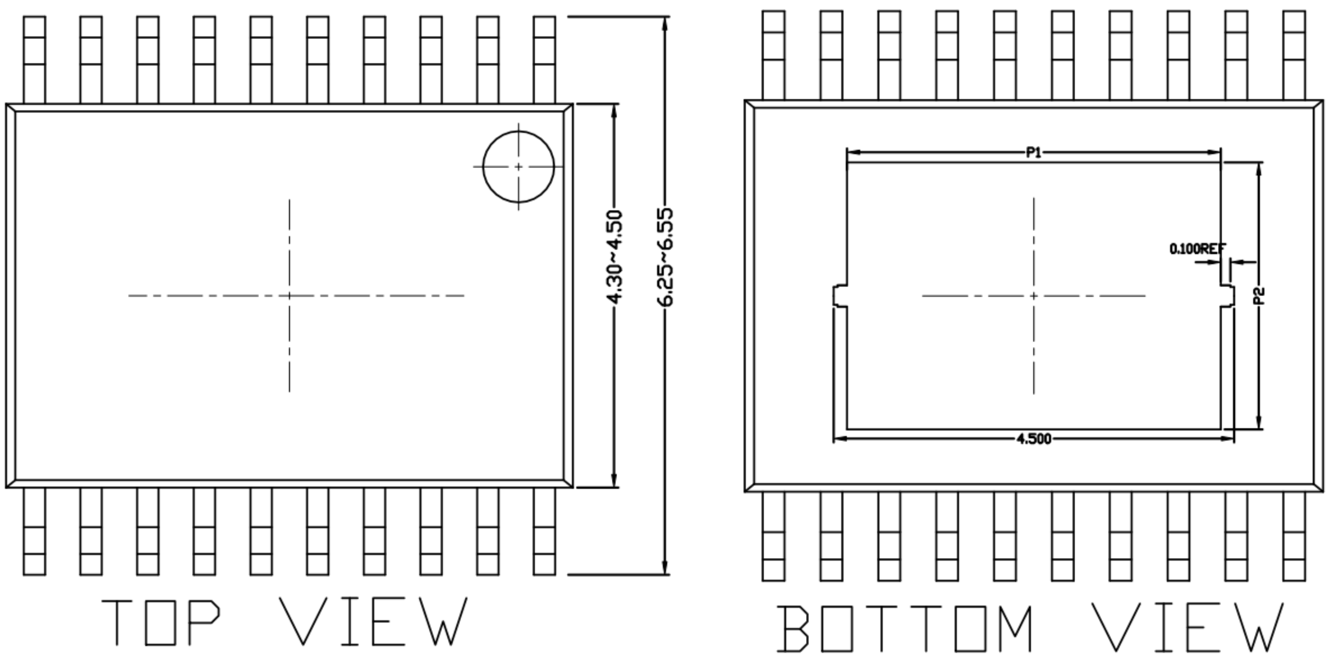
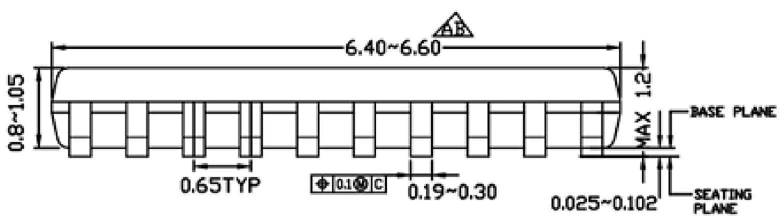


Figure 22. Typical Application for LNQ37000BQ1

11 PACKAGE INFORMATION

11.1 Package Outline





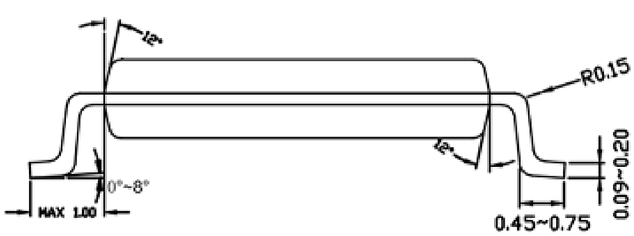


Table for TSSOP20-F of exposed die pad size.

Pad Size	Symbol	Min	Nom	Max
118*165	P1	4.100	4.200	4.300
	P2	2.900	3.000	3.100

Notes:

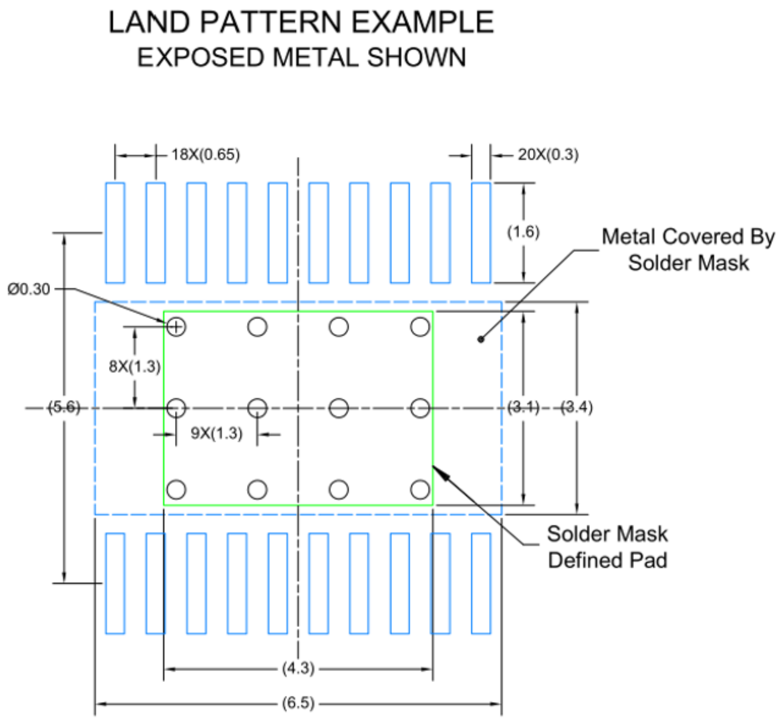
1. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.

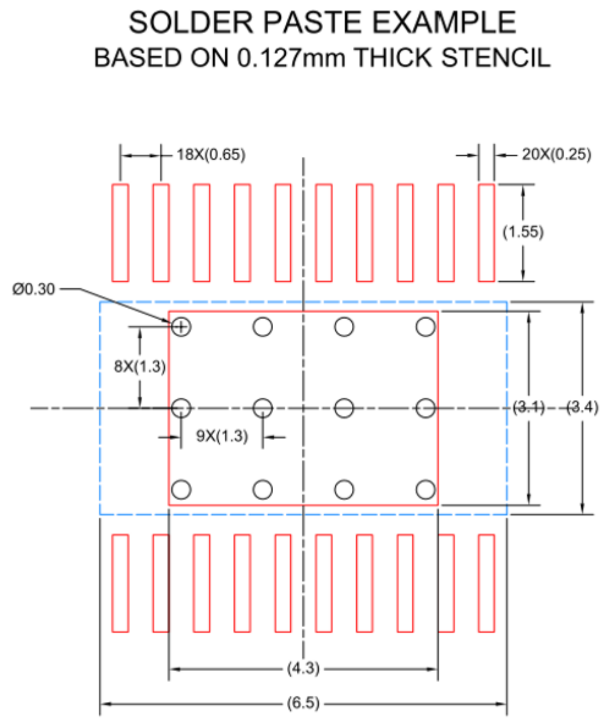
2. Both package length and width does not include mold flash.

3. Unremoved flash between leads & package end flash shall not exceed 0.15mm from bottom body per side.

4. Features may not present.

11.2 Footprint Example





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