

60V Input, 5A Output, Synchronous Step-down Converter

General Description

The ET8650QA is a high voltage, synchronous step-down controller operates over a wide range input voltage 9V to 60V. The ET8650QA delivers 5A continuous load current with up to 96% efficiency.

The ET8650QA operates with fixed frequency peak current control with built-in compensation eliminates the need for external components. Hiccup mode protection is triggered if the over-current condition has persisted for longer than the present time.

The ET8650QA is available in an QFN20.

Features

- 9V to 60V Input Voltage Range
- 5A Continuous Output Current
- 96% Peak Efficiency
- 500 μ A Operating Quiescent Current
- Peak Current Mode Control
- 60V 20 m Ω High-Side and Low-Side MOSFET
- 150 kHz Fixed Frequency
- Internal Compensation for Ease of Use
- Up to 91% Duty Cycle
- 0.8V Voltage Reference
- 9 μ A Shutdown Current
- Hiccup Mode Short Circuit Protection
- Thermal Shutdown Function
- Package:

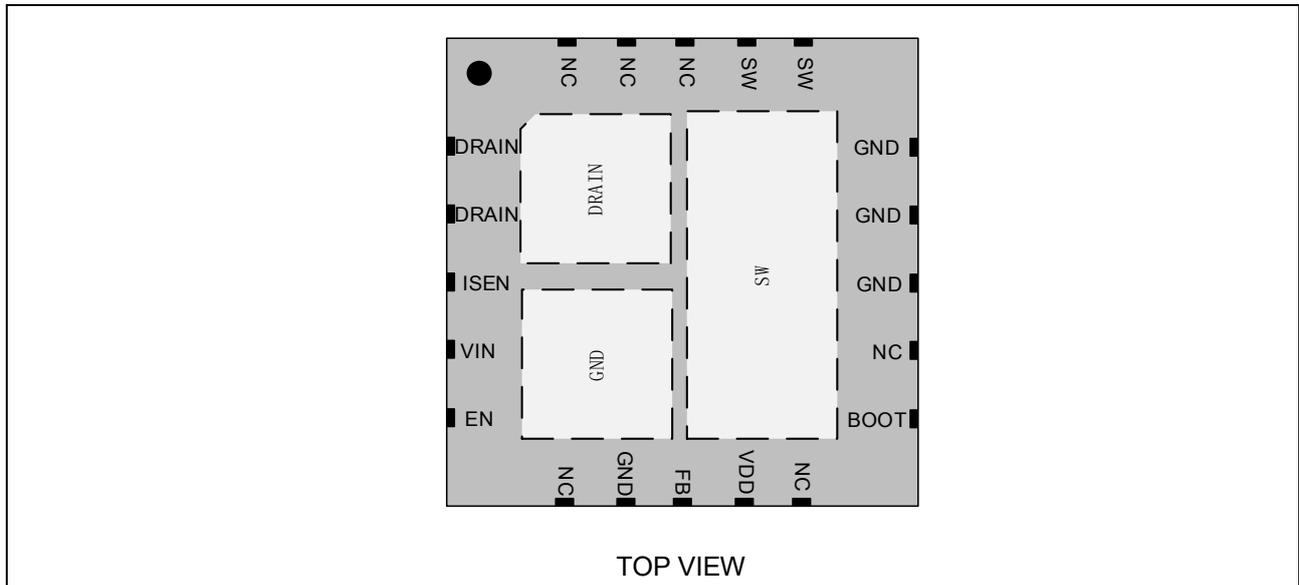
Part No.	Package	Body Size	Reel
ET8650QA	QFN20	5.0mm × 5.0mm	4000pcs/reel

Applications

- Charger in Vehicle
- Battery Chargers
- Power Adapter

ET8650QA

Pin Configuration

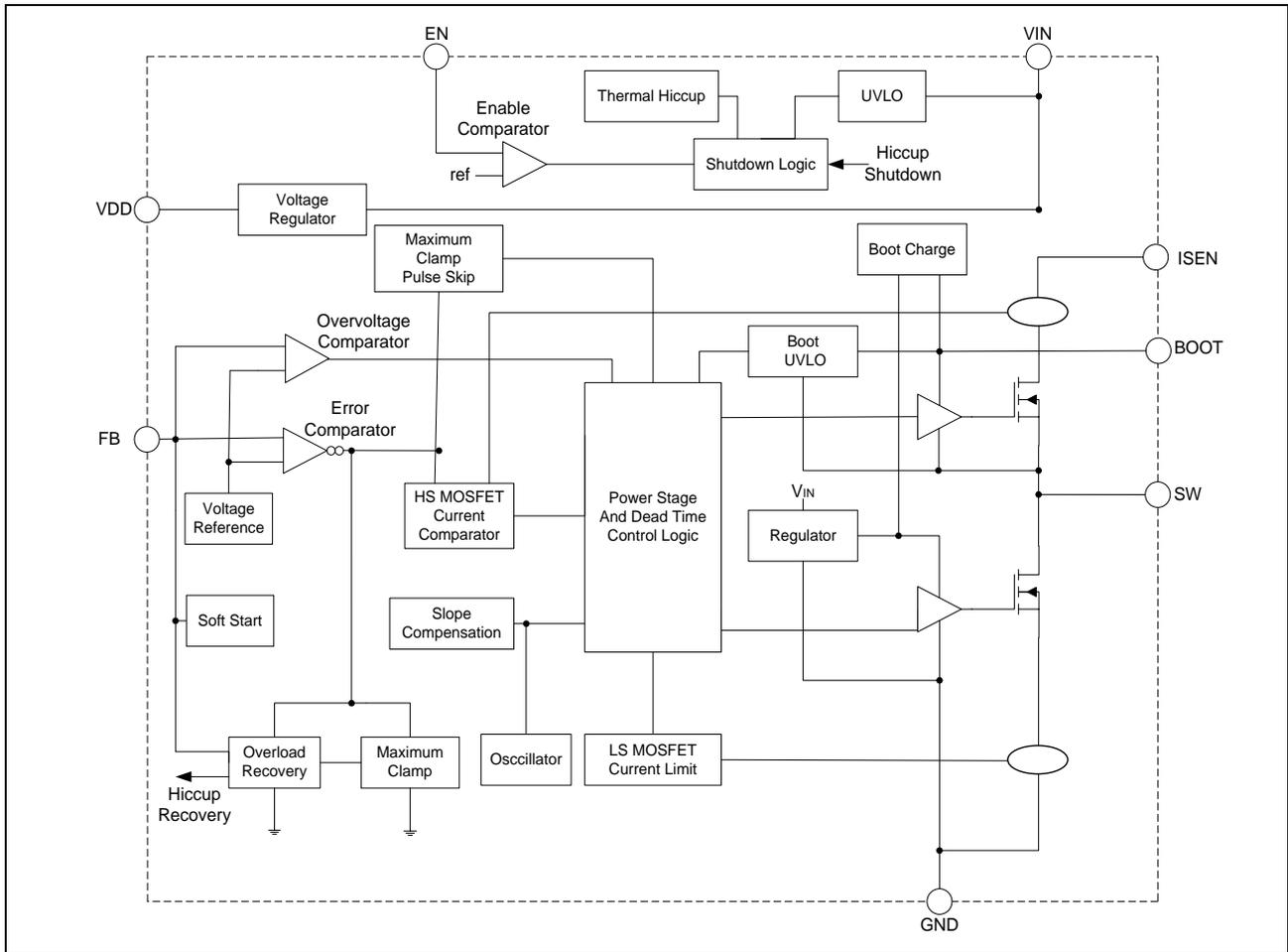


Pin Function

Pin No.	Pin Name	Pin Function
1,2	DRAIN	It is a chip that is responsible for the transformation, distribution, detection and other power management of electric energy in the electronic equipment system.
3	ISEN	Connecting a resistance from ISEN to VIN sets the output short circuit detection threshold.
4	VIN	Input supply. VIN supplies power to all of the internal control circuitry, both BOOT regulators, and the high-side switch.
5	EN	Enable input. Pull EN below the specified threshold to shut down the MST8A50Q7. Pull EN above the specified threshold or leave EN floating to enable the MST8A50Q7.
7,13,14,15	GND	Ground. GND should be placed as close to the output capacitor as possible to avoid the high-current switch paths. Connect the exposed pad to GND plane for optimal thermal performance.
8	FB	Feedback. FB is the input to the voltage hysteresis comparator. The average FB voltage is maintained at 800mV by loop regulation.
9	VDD	Power input to the controller.
11	BOOT	Power supply of high-side NFET control circuit. Connect 0.1μF capacitor between VBST and SW pins.
16,17	SW	Switch node. SW is the output from the high-side switch. A low forward voltage Schottky rectifier to ground is required. The rectifier must be placed close to SW to reduce switching spikes.
6,10,12,18, 19,20	NC	No Connection.

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Block Diagram



Absolute Maximum Ratings

Symbol	Parameters	Min	Max	Unit
$V_{EN}, V_{IN}, V_{ISEN}, V_{SW}$	$V_{EN}, V_{IN}, V_{ISEN}, V_{SW}$ to GND Voltage	-0.3	70	V
V_{FB}, V_{DD}	V_{FB}, V_{DD} to GND Voltage	-0.3	7	V
V_{BOOT}	BOOT to GND	-0.3	70	V
	BOOT to SW	-0.3	5.5	V
T_{STG}	Storage Junction Temperature	-55	150	°C
V_{ESD}	HBM	-2	2	KV

Note: Stresses beyond those listed under absolute maximum ratings may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under recommended operating conditions. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

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Electrical Characteristics

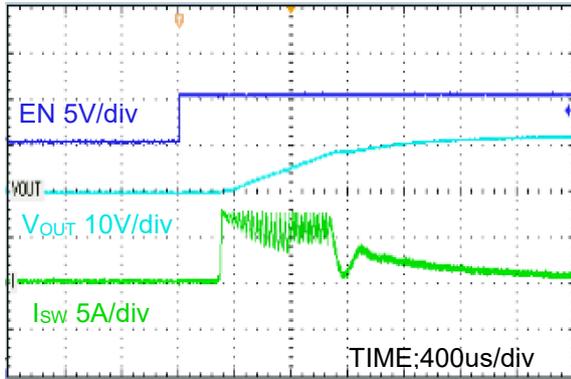
($V_{IN} = 48V$, $V_{OUT} = 5V$, Typical values are at $T_A = 25^\circ C$ unless otherwise noted)

Symbol	Parameters	Conditions	Min	Typ	Max	Unit
SUPPLY VOLTAGE						
V_{IN}	Input Voltage		9	-	60	V
V_{IN_UVLO}	UVLO	V_{IN} Rising		8		V
$V_{UVLO(HYS)}$	UVLO Hysteresis			0.3		V
I_{SHUT}	Shutdown Supply Current	EN=0V, No Load		9		uA
I_Q	Input Quiescent Current	EN floating, No Load, Non-Switching		500		uA
ENABLE						
V_{EN}	Enable Threshold Voltage		-	2.2	-	V
V_{EN_UVLO}	Enable Threshold voltage Hysteresis		-	0.2	-	V
V_{EN_MAX}			60	-	-	V
FEEDBACK						
V_{FB}	FB Reference Threshold		-	0.8	-	V
V_{FB_short}	Feedback Short Voltage		-	0.1	-	V
V_{FB2}	Feedback Short Voltage Hysteresis		-	0.12	-	V
OSCILLATOR						
F		$I_{OUT}=500mA$	-	150	-	KHz
D_{MAX}	Maximum Duty Cycle	$V_{IN}=12V$	-	91	-	%
VDD						
VDD	VDD Voltage		-	5.4	-	V
CURRENT LIMIT						
V_{SEN}	Cycle-By-Cycle Sense Voltage		-	125	-	mV
THERMAL SHUTDOWN						
T_{SD}	Thermal Shutdown Temp		-	130	-	$^\circ C$
T_{SH}	Thermal Shutdown Temp Hysteresis		-	20	-	$^\circ C$

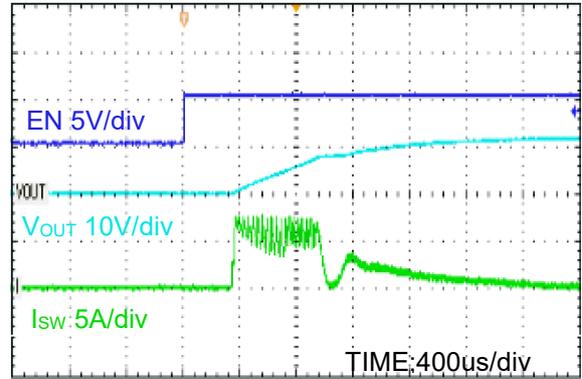
ET8650QA

Typical Characteristics

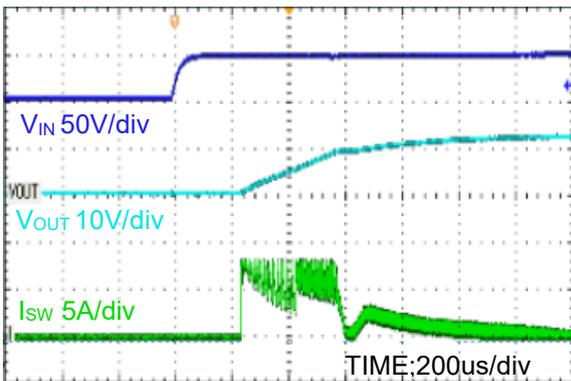
(At $T_A = 25^\circ\text{C}$, $V_{IN} = 48\text{V}$, $V_{OUT} = 12\text{V}$, Unless Otherwise Noted)



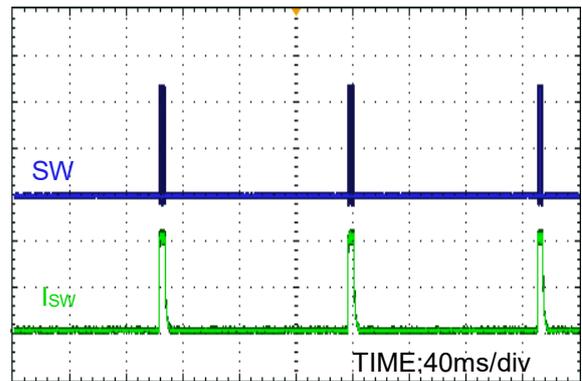
$V_{IN}=48\text{V}$ $EN=5\text{V}$ $I_{OUT}=1\text{A}$
Figure1 EN Start up



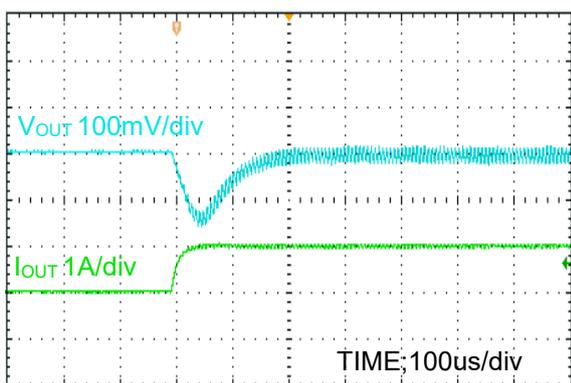
$V_{IN}=48\text{V}$ $EN=5\text{V}$ $I_{OUT}=0\text{A}$
Figure2 EN Start up



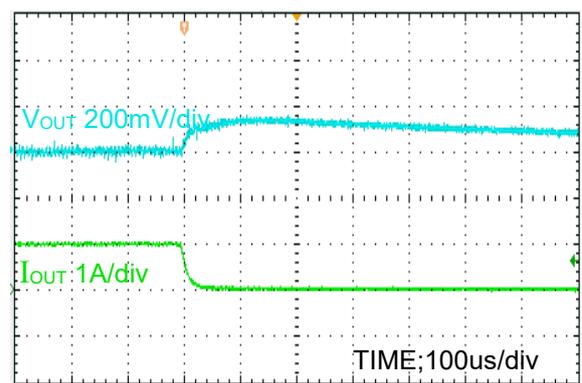
$V_{IN}=48\text{V}$ $I_{OUT}=0\text{A}$
Figure3 Start up



$V_{IN}=48\text{V}$
Figure4 Short Hiccup Mode



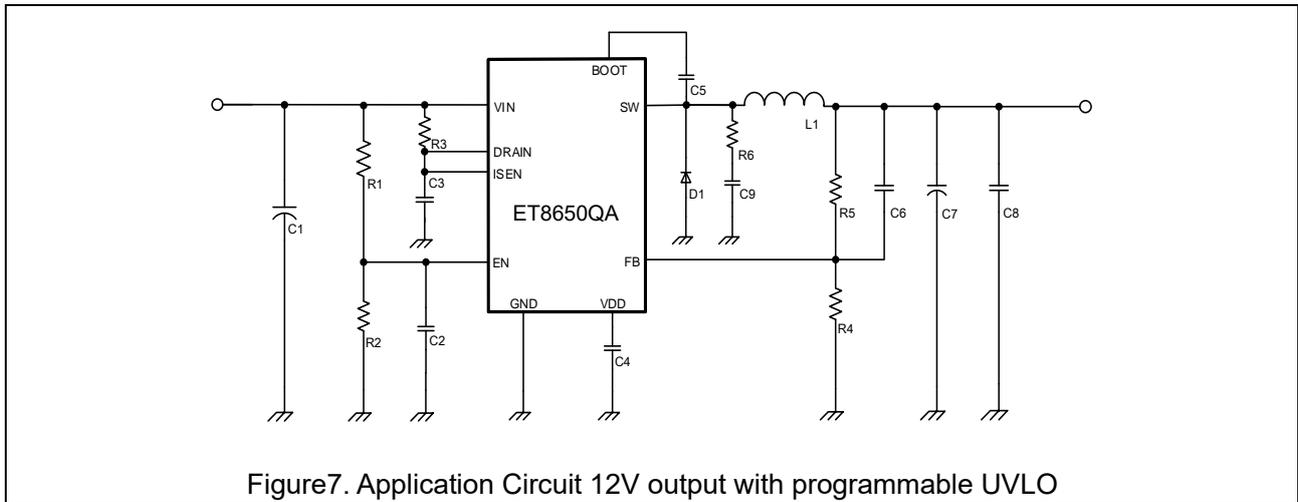
$I_{OUT}=10\text{mA}\sim 1\text{A}$ $V_{IN}=48\text{V}$
Figure5 Load Transient



$I_{OUT}=1\text{A}\sim 10\text{mA}$ $V_{IN}=48\text{V}$
Figure6 Load Transient

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Application Circuits

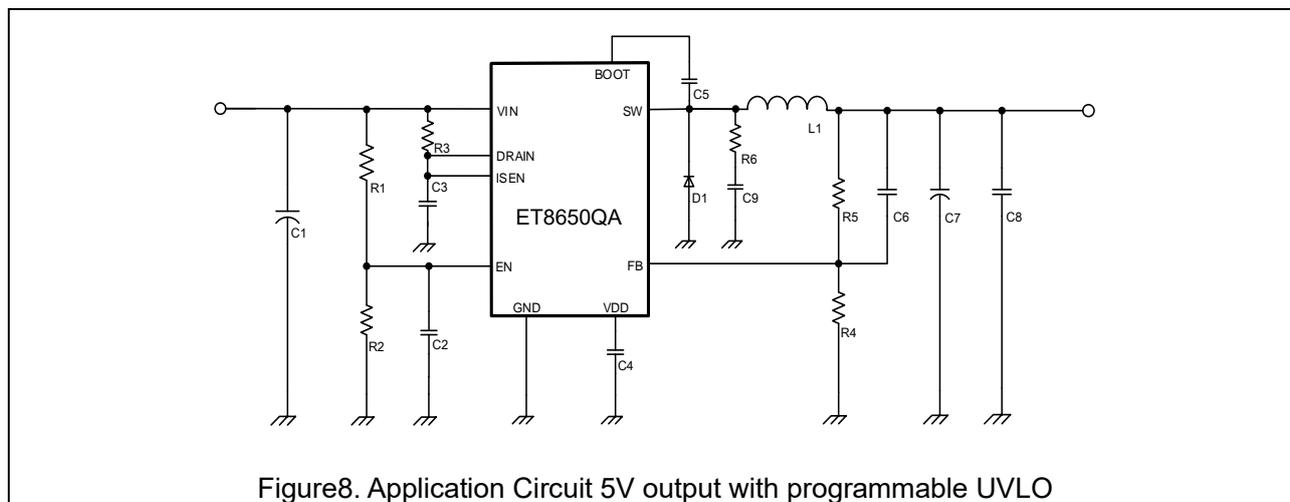


ID	Parameters	Type	Part Number	Vendor
U1		DFN-20	ET8650QA	ETEK
C1	47uF	Capacitor, 47uF, 100V, 20%	ERS1KM470G13OT	AISHI
C2	10uF	Capacitor, 10uF, 10V, 20%, 0603	CL10A106MP8NNNC	SAMSUNG
C3	1uF	Capacitor, 1uF, 100V, 10%, 0805	CGA0805X7R105K101MT	HRE
C5	0.1uF	Capacitor, 0.1uF, 50V, 10%, 0603	CL10B104KB8NNNC	SAMSUNG
C9	470pF	Capacitor, 470pF, 100V, 10%, 0805	FCC0805B471K101DT	FOJAN
C7	470uF	Capacitor, 470uF, 25V, 20%	C025M471LO10*12TH-2A1 E	BERYL
C4	1uF	Capacitor, 1uF, 10V, 10%, 0805	CGA0805X7R105K100MT	HRE
C8	10uF	Capacitor, 10uF, 25V, 10%, 0805	CL21A106KAYNNNE	SAMSUNG
C6	100pF	Capacitor, 100pF, 50V, 10%, 0603	CC0603KRX7R9BB101	YAGEO
R1	100kΩ	Resistor, 100K, 1%, 0603	RC0603FR-07100KL	YAGEO
R2	10kΩ	Resistor, 10K, 1%, 0603	RT0603BRD0710KL	YAGEO
R3	25mΩ	Resistor, 25mΩ, 5%, 1206	LRAN12CJTR025	NCT
R5	43kΩ	Resistor, 43K, 1%, 0603	RC0603FR-0743KL	YAGEO
R4	3kΩ	Resistor, 3K, 1%, 0603	RC0603FR-073KL	YAGEO
R6	10Ω	Resistor, 10Ω, 5%, 1206	RC1206JR-7W10RL	YAGEO
D1	3A	Diode, 3A, 100V	SS310FL	GOODWORK
L1	68uH	Inductance, 68uH, 5A	MWSA1206S-680MT	ZE

Design Parameters	Example Value
Input voltage	48V
Output voltage	12V
Maximum output current	3A
Start input voltage (rising VIN)	24V
Stop input voltage (falling VIN)	22V

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Application Circuits (Continued)



ID	Parameters	Type	Part Number	Vendor
U1		DFN-20	ET8650QA	ETEK
C1	47uF	Capacitor, 47uF, 100V, 20%	ERS1KM470G13OT	AISHI
C2	10uF	Capacitor, 10uF, 10V, 20%, 0603	CL10A106MP8NNNC	SAMSUNG
C3	1uF	Capacitor, 1uF, 100V, 10%, 0805	CGA0805X7R105K101MT	HRE
C5	0.1uF	Capacitor, 0.1uF, 50V, 10%, 0603	CL10B104KB8NNNC	SAMSUNG
C9	470pF	Capacitor, 470pF, 100V, 10%, 0805	FCC0805B471K101DT	FOJAN
C7	470uF	Capacitor, 470uF, 25V, 20%	C025M471LO10*12TH-2A1 E	BERYL
C4	1uF	Capacitor, 1uF, 10V, 10%, 0805	CGA0805X7R105K100MT	HRE
C8	10uF	Capacitor, 10uF, 25V, 10%, 0805	CL21A106KAYNNNE	SAMSUNG
C6	100pF	Capacitor, 100pF, 50V, 10%, 0603	CC0603KRX7R9BB101	YAGEO
R1	100kΩ	Resistor, 100K, 1%, 0603	RC0603FR-07100KL	YAGEO
R2	10kΩ	Resistor, 10K, 1%, 0603	RT0603BRD0710KL	YAGEO
R3	25mΩ	Resistor, 25mΩ, 5%, 1206	LRAN12CJTR025	NCT
R5	16kΩ	Resistor, 16K, 1%, 0603	RC0603FR-0716KL	YAGEO
R4	3kΩ	Resistor, 3K, 1%, 0603	RC0603FR-073KL	YAGEO
R6	10Ω	Resistor, 10R, 5%, 1206	RC1206JR-7W10RL	YAGEO
D1	3A	Diode, 3A, 100V	SS310FL	GOODWORK
L1	68uH	Inductance, 68uH, 5A	MWSA1206S-680MT	ZE

Design Parameters	Example Value
Input voltage	48V
Output voltage	5V
Maximum output current	3A
Start input voltage (rising VIN)	24V
Stop input voltage (falling VIN)	22V

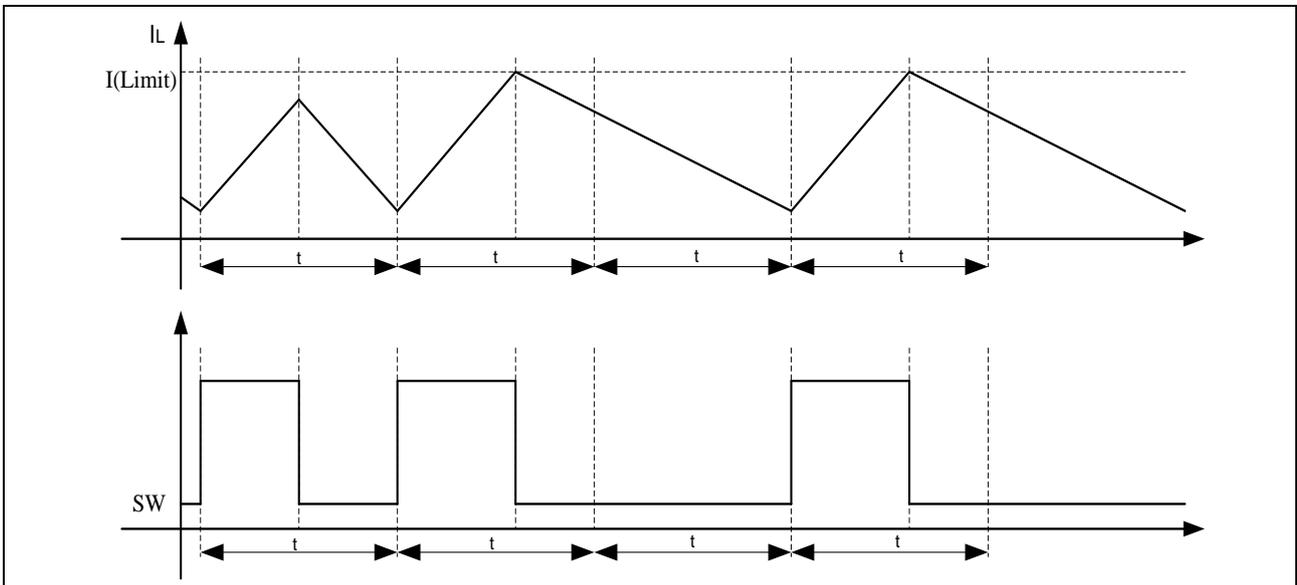
ET8650QA

Overview

The ET8650QA is a high voltage, synchronous step-down controller operates over a wide range input voltage 9V to 60V. The ET8650QA delivers 5A continuous load current with up to 96% efficiency. The ET8650QA operates with fixed frequency peak current control with built-in compensation eliminates the need for external components. Hiccup mode protection is triggered if the over-current condition has persisted for longer than the present time.

Over-current Protection

The ET8650QA implements current-mode control which uses the internal COMP voltage to control the turn on and the turnoff of the high-side MOSFET on a cycle-by-cycle basis. During each cycle, the switch current and the current reference generated by the internal COMP voltage are compared. When the peak switch current intersects the current reference the SW switch turns off.



Output Voltage

The output voltage is set by an external resistor divider $R4$ and $R5$ in typical application schematic. Recommended $R4$ resistance is $3k\Omega$. Use [Equation 1](#) to calculate $R5$, $V_{REF}=0.8V$.

$$R5 = \left(\frac{V_{OUT}}{V_{REF}} - 1 \right) \times R4 \quad (1)$$

Under Voltage Lock-Out

An external voltage divider network of $R1$ from the input to EN pin and $R2$ from EN pin to the ground can set the input voltage's Under Voltage Lock-Out (UVLO) threshold, $V_{EN}=2.2V$. Use [Equation 2](#) to calculate.

$$R1 = \left(\frac{V_{UVLO}}{V_{EN}} - 1 \right) \times R2 \quad (2)$$

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Inductor Selection

There are several factors should be considered in selecting inductor such as inductance, saturation current, RMS current and DC resistance (DCR). Larger inductance results in less inductor current ripple and therefore leads to lower output voltage ripple. However, the larger value inductor always corresponds to a bigger physical size, higher series resistance, and lower saturation current. A good rule for determining the inductance to use is to allow inductor peak-to-peak ripple current to be approximately 20%~40% of the maximum output current. The peak-to-peak ripple current in the inductor I_{LPP} can be calculated as in [Equation 3](#).

$$I_{LPP} = \frac{V_{OUT} - (V_{IN} - V_{OUT})}{V_{IN} \times L \times F_{SW}} \quad (3)$$

- I_{LPP} is the inductor peak-to-peak current
- L is the inductance of inductor
- F_{SW} is the switching frequency
- V_{OUT} is the output voltage
- V_{IN} is the input voltage

Since the inductor-current ripple increases with the input voltage, so the maximum input voltage is always used to calculate the minimum inductance required. Use [Equation 4](#) to calculate the inductance value

$$L_{MIN} = \frac{V_{OUT}}{F_{SW} \times LIR \times I_{OUT(MAX)}} \times \left(1 - \frac{V_{OUT}}{V_{IN(MAX)}}\right) \quad (4)$$

- L_{MIN} is the minimum inductance required
- f_{sw} is the switching frequency
- V_{OUT} is the output voltage
- $V_{IN(max)}$ is the maximum input voltage
- $I_{OUT(max)}$ is the maximum DC load current
- LIR is coefficient of I_{LPP} to I_{OUT}

The total current flowing through the inductor is the inductor ripple current plus the output current. When selecting inductor, choose its rated current especially the saturation current larger than peak current and RMS current also not be exceeded. Therefore, the peak switching current of inductor, I_{LPEAK} and I_{LRMS} can be calculated as in [Equation 5](#) and [Equation 6](#).

$$I_{LPEAK} = I_{OUT} + \frac{I_{LPP}}{2} \quad (5)$$

$$I_{LRMS} = \sqrt{(I_{OUT})^2 + \frac{1}{12} \times (I_{LPP})^2} \quad (6)$$

- I_{LPEAK} is the inductor peak current
- I_{OUT} is the DC load current
- I_{LPP} is the inductor peak-to-peak current

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- I_{LRMS} is the inductor RMS current

In overloading or load transient conditions, the inductor peak current can increase up to the switch current limit of device which is typically 5A. The most conservative approach is to choose an inductor with saturation current greater than 5A. Because of the maximum I_{LPEAK} limited by device, maximum output current that can deliver depends on inductor current ripple. Thus, maximum desired output current affects the selection of inductance. The smaller inductor results in larger inductor current ripple leading to lower maximum output current.

Diode Selection

Requires an external catch diode between the SW pin and GND. The selected diode must have reverse voltage rating equal to or greater than $V_{IN(max)}$. The peak current rating of the diode must be greater than the maximum inductor current. Schottky diodes are typically a good choice for the catch diode due to low forward voltage. The lower the forward voltage of the diode, the higher the efficiency of the regulator.

Typically, diodes with higher voltage and current ratings have higher forward voltages. A diode with a minimum of 100V reverse voltage is preferred to allow input voltage transients up to the rated voltage of the ET8650QA.

For the example design, the SS310 Schottky diode is selected for its lower forward voltage and good thermal characteristics compared to smaller devices. The typical forward voltage of the SS310FL is 0.67 volts at 3A.

The diode must also be selected with an appropriate power rating. The diode conducts the output current during the off-time of the internal power switch.

The off-time of the internal switch is a function of the maximum input-voltage, the output voltage, and the switching frequency. The output current during the off-time is multiplied by the forward voltage of the diode to calculate the instantaneous conduction losses of the diode.

Input Capacitor Selection

The input current to the step-down DCDC converter is discontinuous, therefore it requires a capacitor to supply AC current to the step-down DCDC converter while maintaining the DC input voltage. Use capacitors with low ESR better performance. Ceramic capacitors with X5R or X7R dielectrics are usually suggested low ESR and small temperature coefficients, and it is strongly recommended to use another lower value capacitor (e.g. 1uF) with small package size (0805) to filter high frequency switching noise. Place the small size cap to V_{IN} and GND pins as possible.

The voltage rating of the input capacitor must be greater than the maximum input voltage. And the capacitor must have a ripple current rating greater than the maximum input current ripple. Use [Equation 7](#) and [Equation 8](#) and [Equation 9](#) to calculate.

$$I_{CINRMS} = I_{OUT} \times \sqrt{\frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)} \quad (7)$$

The worst case condition occurs at $V_{IN}=2*V_{OUT}$, where:

$$I_{CINRMS} = 0.5 \times I_{OUT} \quad (8)$$

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$$\Delta V_{IN} = \frac{I_{OUT}}{F_{SW} \times C_{IN}} \times \frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \quad (9)$$

For this example, four 4.7uF, X7R ceramic capacitors rated for 100 V in parallel are used. And a 0.1uF for high-Frequency filtering capacitor is placed as close as possible to the device pins.

Bootstrap Capacitor Selection

A 0.1F ceramic capacitor must be connected between BOOT pin and SW pin for proper operation. capacitor with X5R or better grade dielectric is recommended. The capacitor should have a 10V or higher voltage rating.

Output Capacitor Selection

The selection of output capacitor will affect output voltage ripple in steady state and load transient performance. The output ripple is essentially composed of two parts. One is caused by the inductor current ripple going through the Equivalent Series Resistance ESR of the output capacitors and the other is caused by the inductor current ripple charging and discharging the output capacitors. To achieve small output voltage ripple, choose a low-ESR output capacitor like ceramic capacitor. For ceramic capacitors, the capacitance dominates the output ripple. For simplification, the output voltage ripple can be estimated by [Equation 10](#) desired.

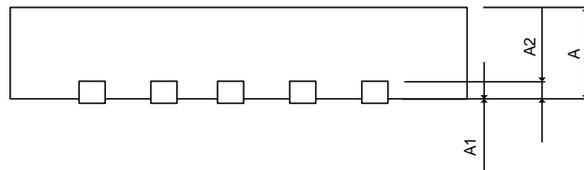
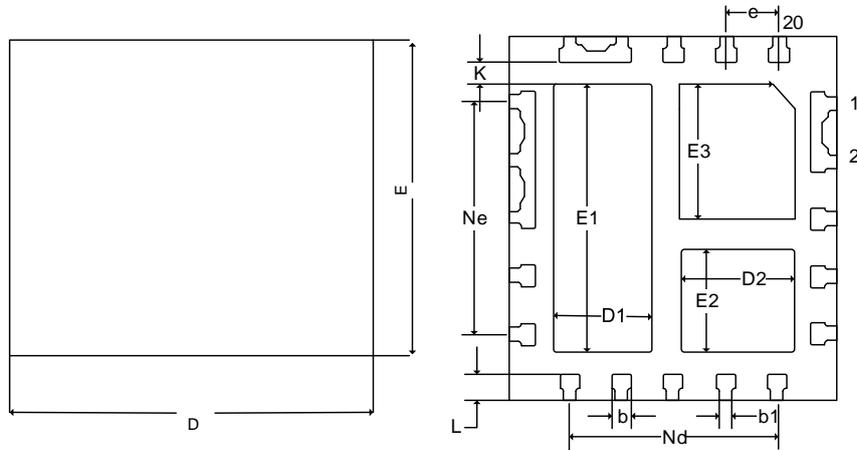
$$\Delta V_{OUT} = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{8 \times F_{SW}^2 \times L \times C_{OUT} \times V_{IN}} \quad (10)$$

- ΔV_{OUT} is the output voltage ripple
- F_{SW} is the switching frequency
- L is the inductance of inductor
- C_{OUT} is the output capacitance
- V_{OUT} is the output voltage
- V_{IN} is the input voltage

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Package Dimension

QFN20

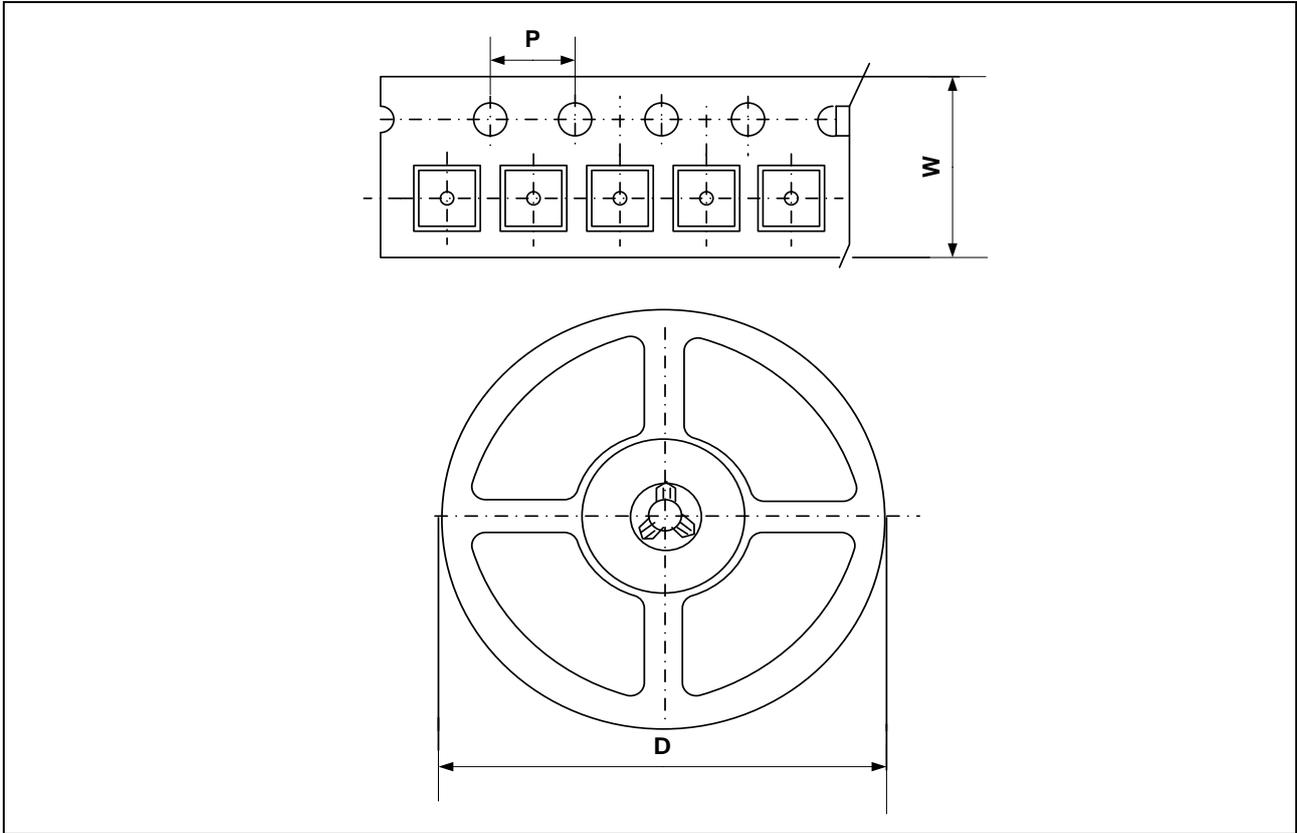


COMMON DIMENSIONS
(UNITS OF MEASURE=MILLIMETER)

SYMBOL	MIN	NOM	MAX
A	0.70	0.75	0.80
A1	0.00	-	0.05
A2	0.19	0.20	0.21
b	0.25	0.30	0.35
D	4.95	5.00	5.05
D1	1.40	1.50	1.60
D2	1.65	1.75	1.85
E	4.95	5.00	5.05
E1	3.60	3.70	3.80
E2	1.30	1.40	1.50
E3	1.75	1.85	1.95
e	-	0.8	-
L	0.25	0.35	0.45
K	0.25	0.30	0.35
Nd	-	3.20	-
Ne	-	3.20	-

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Packing Information



Type	W(mm)	P(mm)	D(mm)	Qty (pcs)
QFN20	16.0 mm	4.0 mm	330±1 mm	4000pcs

Revision History and Checking Table

Version	Date	Revision Item	Modifier	Function & Spec Checking	Package & Tape Checking
1.0	2026-01-10	Initial Version	Liucong	Wuhsong	Liujiaying