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

## General Description

The ET8650Q7 is a high voltage, synchronous step-down controller operates over a wide range input voltage 9V to 60V. The ET8650Q7 delivers 5A continuous load current with up to 96% efficiency.

The ET8650Q7 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 ET8650Q7 is available in an QFN20.

## Features

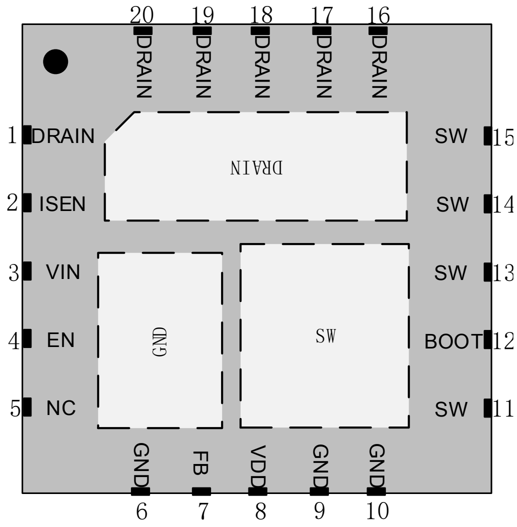
- 9V to 60V Input Voltage Range
- 5A Continuous Output Current
- 96% Peak Efficiency
- 500μA Operating Quiescent Current
- Peak Current Mode Control
- 60V 20 mΩ High-Side and Low-Side MOSFET
- 150 kHz Fixed Frequency
- Internal Compensation for Ease of Use
- Up to 91% Duty Cycle
- 0.8V Voltage Reference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

| **Part No.** | **Package** | **Body Size** | Reel |
|---|---|---|---|
| ET8650Q7 | QFN20 | 7.0mm × 7.0mm | 2500pcs/reel |

## Applications

- Charger in Vehicle
- Battery Chargers
- Power Adapter

## Pin Configuration

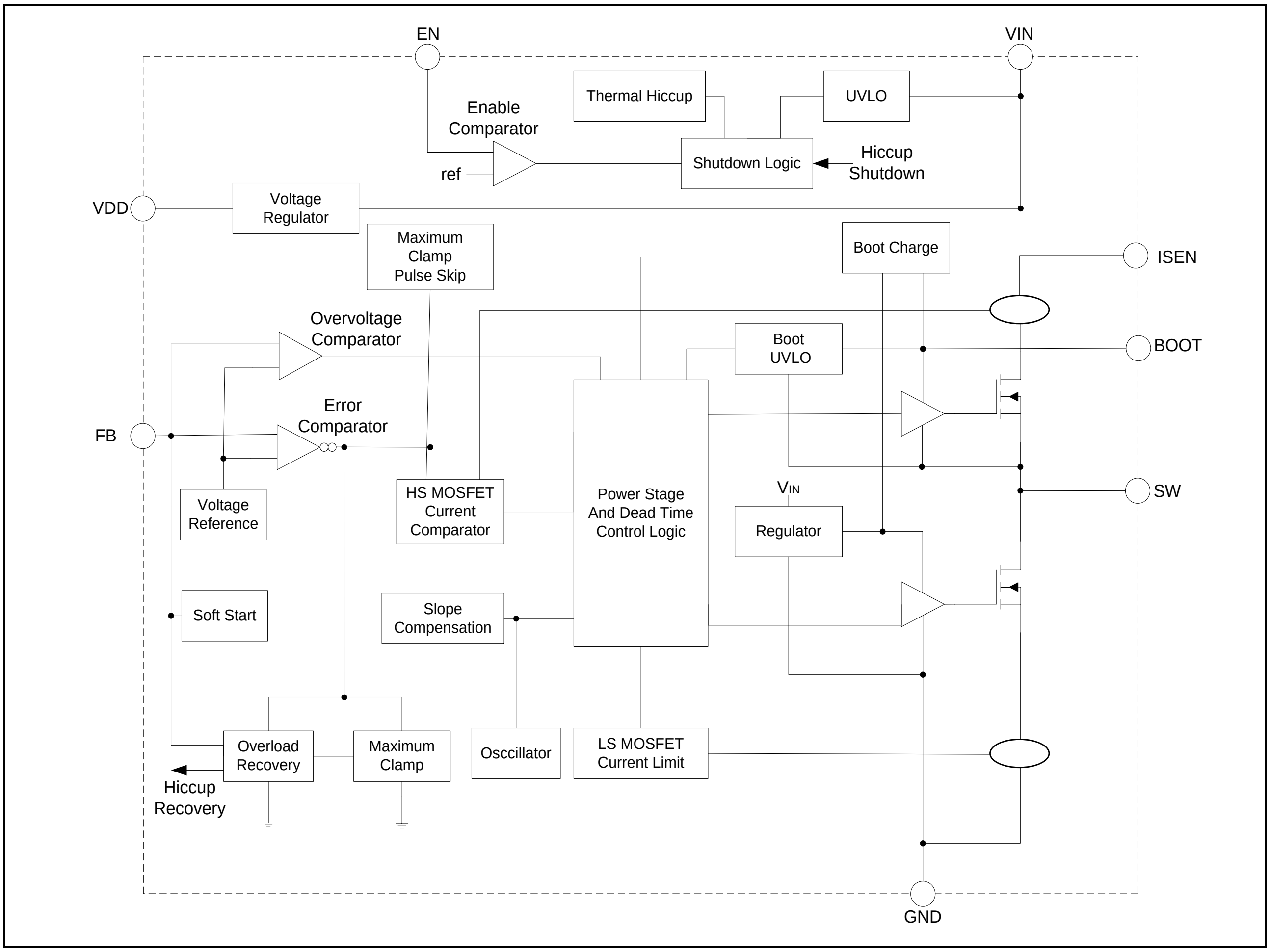


TOP VIEW

## Pin Function

| Pin No. | Pin Name | Pin Function |
|---|---|---|
| 1,16,17,18, 19,20 | 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. |
| 2 | ISEN | Connecting a resistance from ISEN to VIN sets the output short circuit detection threshold. |
| 3 | VIN | Input supply. VIN supplies power to all of the internal control circuity, both BOOT regulators, and the high-side switch. |
| 4 | 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. |
| 5 | NC | No Connection. |
| 6,9,10 | 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. |
| 7 | FB | Feedback. FB is the input to the voltage hysteresis comparator. The average FB voltage is maintained at 800mV by loop regulation. |
| 8 | VDD | Power input to the controller. |
| 11,13,14,15 | SW | Switch node. SW is the output from the high-side switch. A low forward voltage Shottky rectifier to ground is required. The rectifier must be placed close to SW to reduce switching spikes. |
| 12 | BOOT | Power supply of high-side NFET control circuit.<br>Connect 0.1µF capacitor between VBST and SW pins. |

## 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.

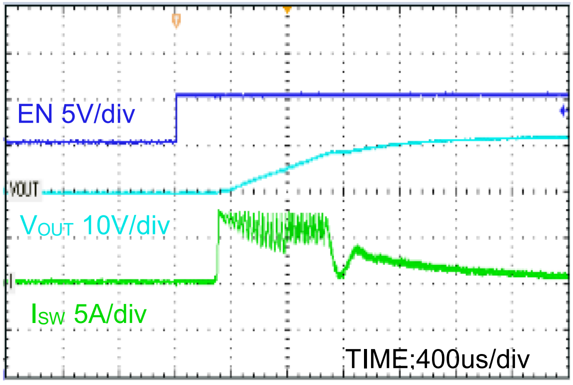
## Electrical Characteristics

($V_{IN}$ = 48V, $V_{OUT}$ = 5V, Typical values are at. $T_A$ = 25°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 | - | °C |
| $T_{SH}$ | Thermal Shutdown Temp Hysteresis | | - | 20 | - | °C |

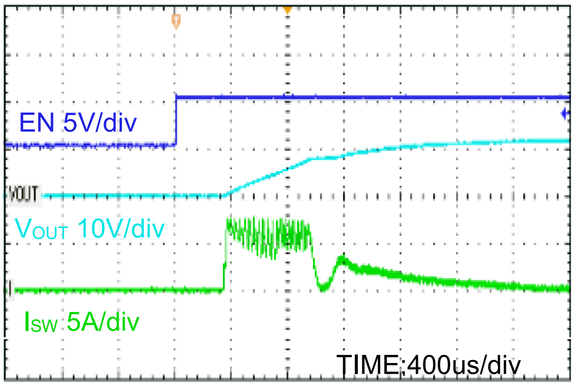
## Typical Characteristics

(At $T_A$ = 25ºC, $V_{IN}$ = 48V, $V_{OUT}$ = 12V, Unless Otherwise Noted)



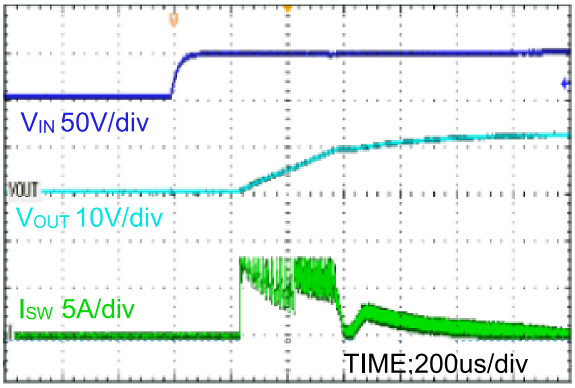

$V_{IN}$=48V EN=5V $I_{OUT}$=1A

Figure1 EN Start up



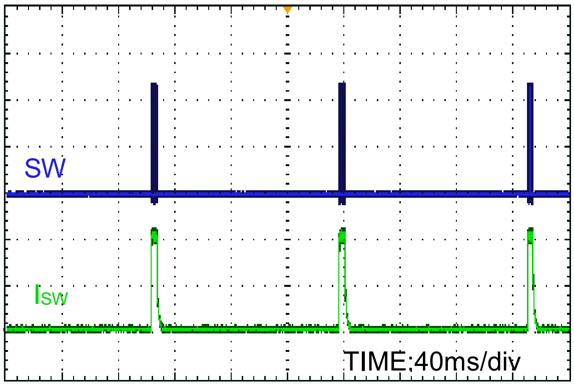

$V_{IN}$=48V EN=5V $I_{OUT}$=0A

Figure2 EN Start up



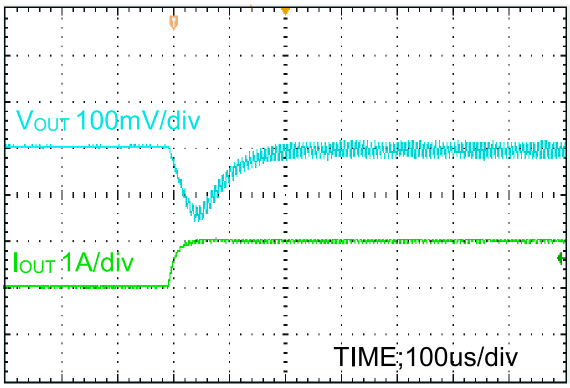

$V_{IN}$=48V $I_{OUT}$=0A

Figure3 Start up



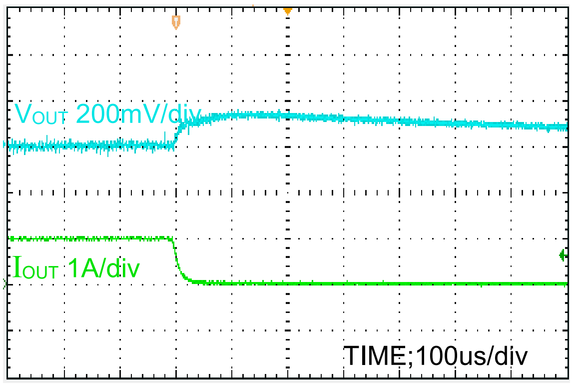

$V_{IN}$=48V

Figure4 Short Hiccup Mode




$I_{OUT}$=10mA~1A $V_{IN}$=48V

Figure5 Load Transient




$I_{OUT}$=1A~10mA $V_{IN}$=48V

Figure6 Load Transient

## Application Circuits

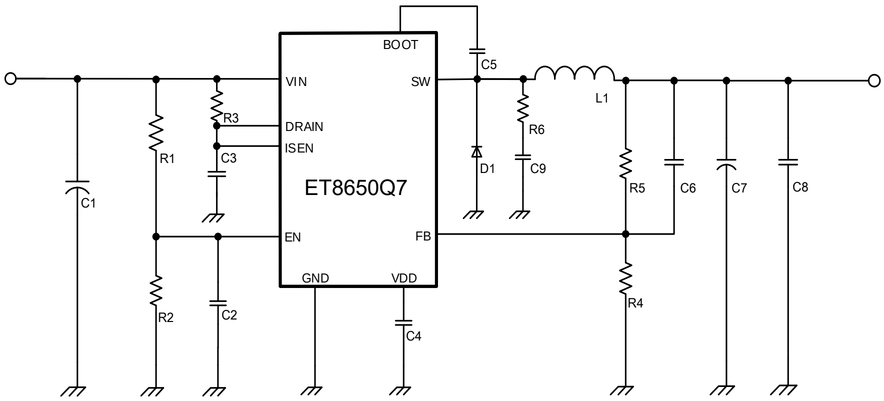



Figure7. Application Circuit 12V output with programmable UVLO

| ID | Parameters | Type | Part Number | Vendor |
|---|---|---|---|---|
| U1 | | DFN-20 | ET8650Q7 | 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 | 20mΩ | Resistor, 20mΩ, 5%, 1206 | LRAN12CJTR020 | 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 | 47uH | Inductance, 47uH, 10A | ZE065125T470M-LS1L | ZE |

| Design Parameters | Example Value |
|---|---|
| Input voltage | 48V |
| Output voltage | 12V |
| Maximum output current | 4A |
| Start input voltage (rising VIN) | 24V |
| Stop input voltage (falling VIN) | 22V |

## Application Circuits (Continued)

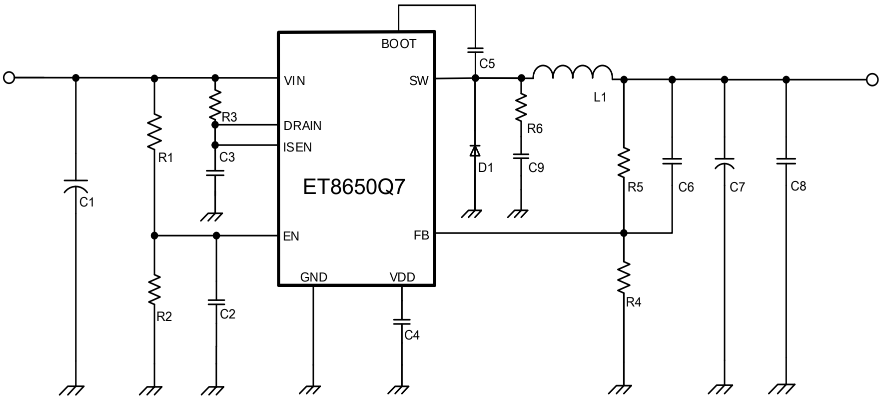



Figure8. Application Circuit 5V output with programmable UVLO

| ID | Parameters | Type | Part Number | Vendor |
|---|---|---|---|---|
| U1 | | DFN-20 | ET8650Q7 | 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-2A1E | 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 | 20mΩ | Resistor, 20mΩ, 5%, 1206 | LRAN12CJTR020 | 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 | 47uH | Inductance, 47uH, 10A | ZE065125T470M-LS1L | ZE |

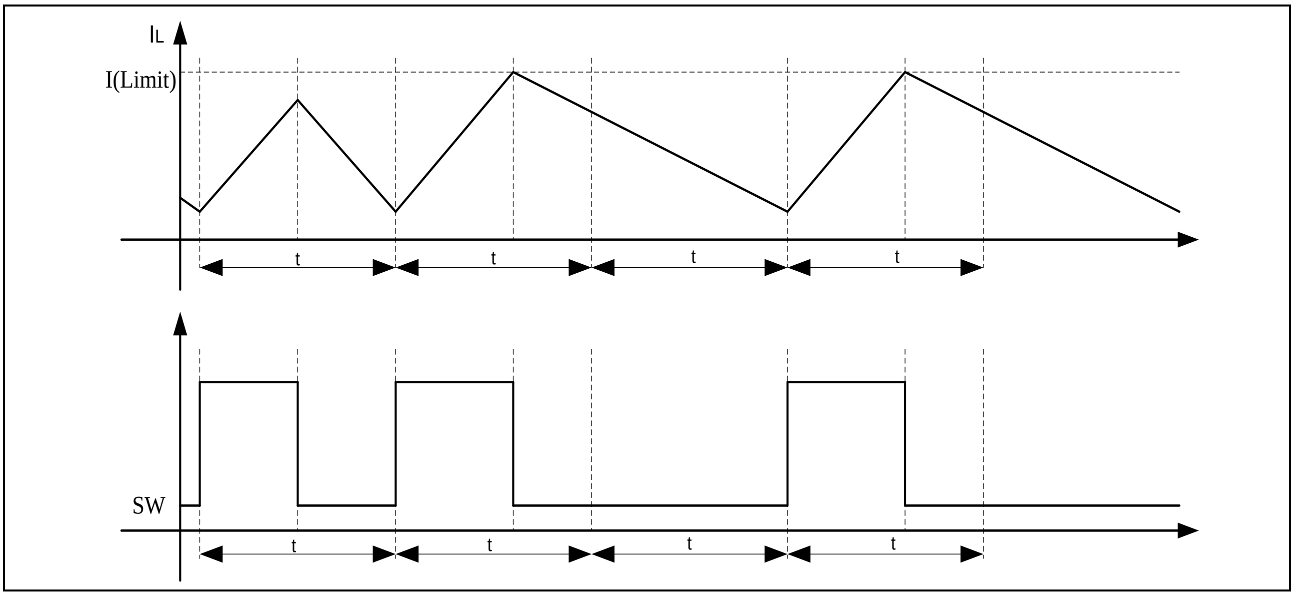
| Design Parameters | Example Value |
|---|---|
| Input voltage | 48V |
| Output voltage | 5V |
| Maximum output current | 4A |
| Start input voltage (rising VIN) | 24V |
| Stop input voltage (falling VIN) | 22V |

## Overview

The ET8650Q7 is a high voltage, synchronous step-down controller operates over a wide range input voltage 9V to 60V. The ET8650Q7 delivers 5A continuous load current with up to 96% efficiency.The ET8650Q7 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 ET8650Q7 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 3kΩ. Use Equation 1 to calculate R5,$V_{REF}$=0.8V.

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

### 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.

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

### 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 ILPP can be calculated as in Equation 3.

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

- $I_{LPP}$ 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

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

- $L_{MIN}$ is the minimum inductance required
- fsw 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.

$$I_{LPEAK} = I_{OUT} + \frac{I_{LPP}}{2} \tag{5}$$

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

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

- $I_{LRMS}$ 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 are verse voltage rating equal to or greater than VIN(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 ET8650Q7. .

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 VIN 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:

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

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

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**

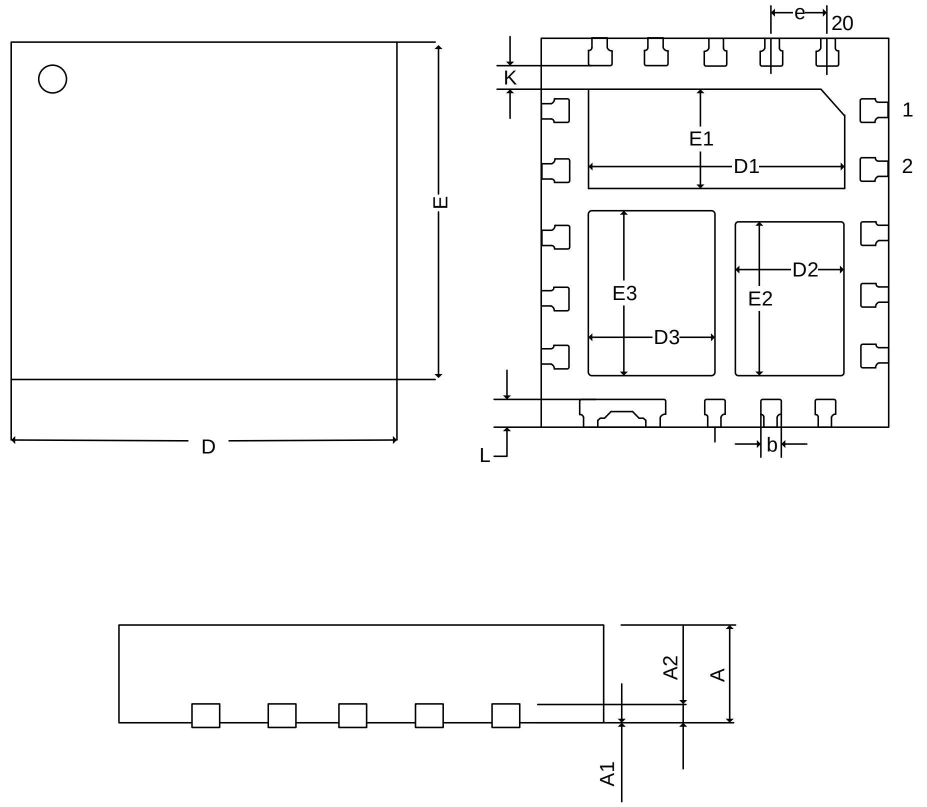
The selection of output capacitor will affect output voltage ripple in steady state and load transient performance.The output ripple is essentially composed of two parts. One is caused by the inductor current ripple going through the Equivalent Series Resistance ESR of the output capacitors and the other 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.

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

- $\Delta V_{OUT}$ 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

## Package Dimension

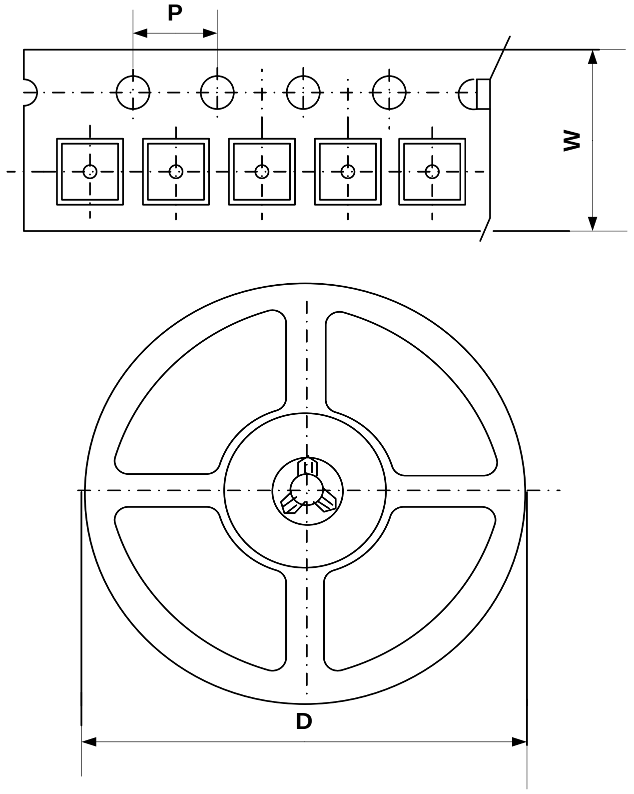
QFN20




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 | 0.375 | 0.425 | 0.475 |
| D | 6.90 | 7.00 | 7.10 |
| D1 | 4.85 | 4.95 | 5.05 |
| D2 | 1.90 | 2.00 | 2.10 |
| D3 | 2.70 | 2.80 | 2.90 |
| E | 6.90 | 7.00 | 7.10 |
| E1 | 1.70 | 1.80 | 1.90 |
| E2 | 2.70 | 2.80 | 2.90 |
| E3 | 3.10 | 3.20 | 3.30 |
| e | - | 1.20 | - |
| L | 0.40 | 0.50 | 0.60 |
| K | 0.35 | 0.40 | 0.45 |

## Packing Information




| Type | W(mm) | P(mm) | D(mm) | Qty (pcs) |
|---|---|---|---|---|
| QFN20 | 16.0 mm | 4.0 mm | 330±1 mm | 2500pcs |

## Revision History and Checking Table

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