3A 30V Synchronous Rectified Step-Down Converter TD2786

General Description

TD2786 is a 3A synchronous buck converter with integrated power MOSFETs. The TD2786 design with a current-mode control scheme, can convert wide input voltage of 4.5V to 30V to the output voltage adjustable from 0.92V to 28V to provide excellent output voltage regulation.

The TD2786 is equipped with an automatic PFM/PWM mode operation. At light load, the IC operates in the PFM mode to reduce the switching losses. At heavy load, the IC works in PWM mode.

The TD2786 is also equipped with Power-on-reset, soft- start, and whole protections (over-temperature, and current-limit) into a single package.

This device, available ESOP-8, provides a very compact system solution external components and PCB area.

Features

- Wide Input Voltage from 4.5V to 30V
- 3A Continuous Output Current
- Adjustable Output Voltage from 0.92V to 28V
- Integrated N-MOSFET
- Fixed 340kHz Switching Frequency
- PFM/PWM mode Operation
- Stable with Low ESR Capacitors
- Power-On-Reset Detection
- Programmable Soft-Start
- Over-Temperature Protection
- Over-Voltage Protection
- Current-Limit Protection with Frequency Foldback
- Enable/Shutdown Function
- Lead Free and Green Devices Available(RoHS Compliant)

Applications

- Distributed Power Systems
- Networking Systems
- FPGA, DSP, ASIC Power Supplies
- Green Electronics/ Appliances
- Notebook Computers

Pin Configurations

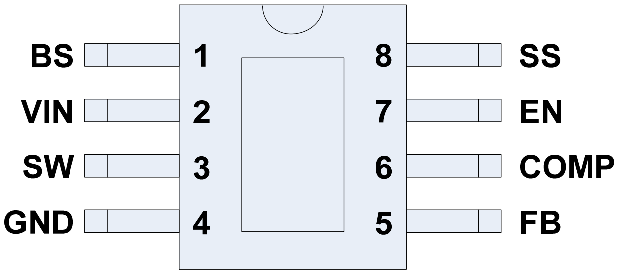
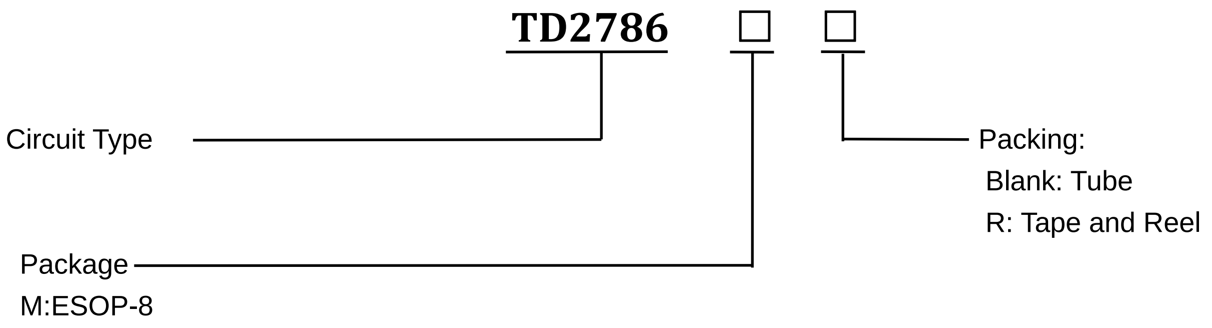


Figure1 Pin Configuration of TD2786(Top View)

Pin Description

Pin Number	**Pin Name**	**Description**
1	BS	High-Side Gate Drive Boost Input. BS supplies the voltage to drive the high-side N-channel MOSFET. At least 10nF capacitor should be connected from SW to BS to supply the high side switch.
2	VIN	Power Input. VIN supplies the power (4.5V to 30V) to the control circuitry, gate drivers and step-down converter switches. Connecting a ceramic bypass capacitor and a suitably large capacitor between VIN and GND eliminates switching noise and voltage ripple on the input to the IC.
3	SW	Power Switching Output. SW is the Drain of the N-Channel power MOSFET to supply power to the output LC filter.
4	GND	Ground.
5	FB	Output feedback Input. The TD2786 senses the feedback voltage via FB and regulates the voltage at 0.92V. Connecting FB with a resistor-divider from the converter's output sets the output voltage from 0.92V to 28V.
6	COMP	Output of the error amplifier. Connect a series RC network from COMP to GND to compensate the regulation control loop. In some cases, an additional capacitor from COMP to GND is required.
7	EN	Enable Input. EN is a digital input that turns the regulator on or off. Pull up with 100k resistor for automatic startup.
8	SS	Soft-Start Control Input. SS controls the soft-start period. Connect a capacitor from SS to GND to set the soft-start period. A 0.1µF capacitor sets the soft-start period to 15ms. To disable the soft-start feature, leave SS unconnected.

Ordering Information



Function Block

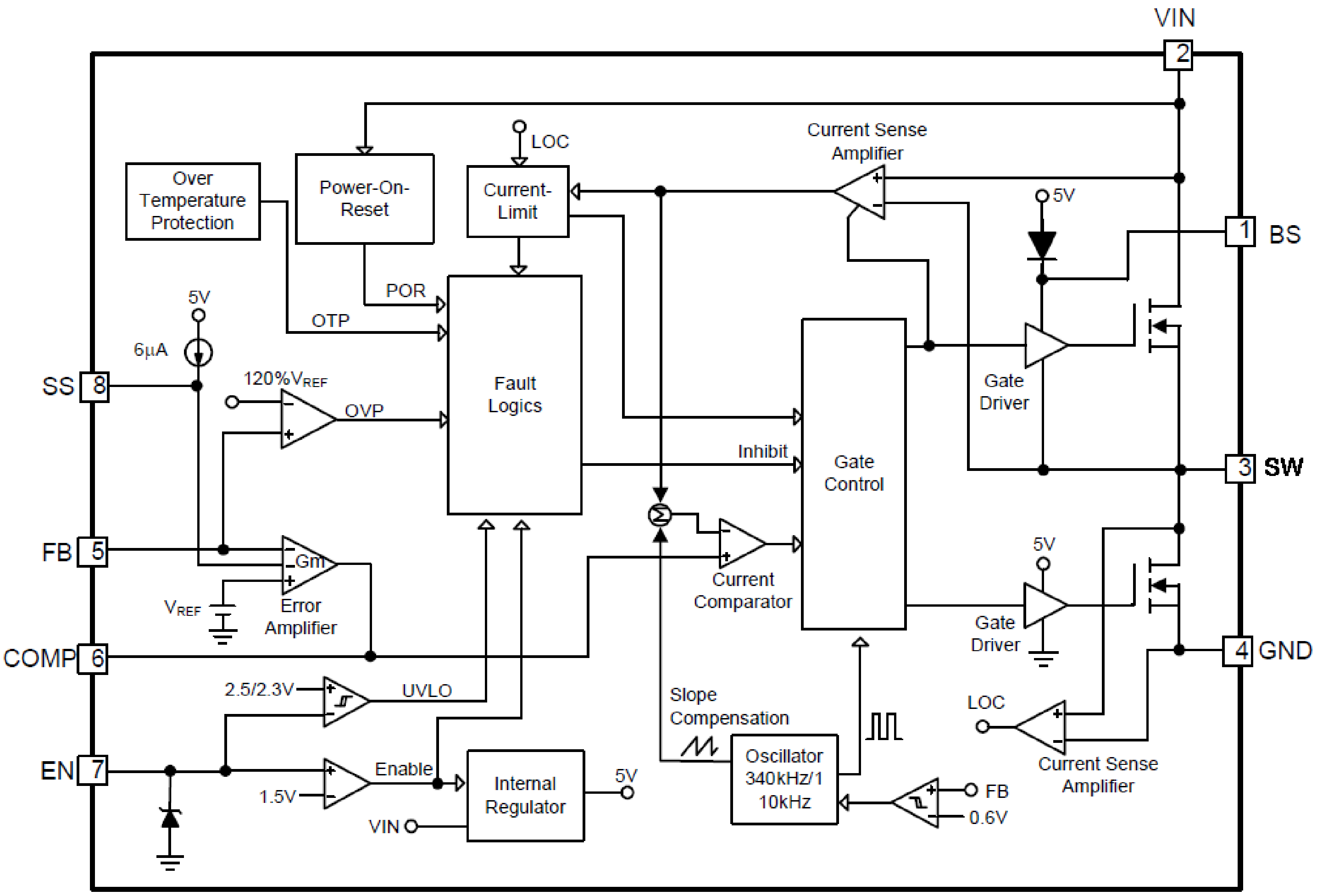


Figure 2 Function Block Diagram of TD2786

Absolute Maximum Ratings

Parameter	symbol	Value	Unit
Input Voltage	V_{IN}	-0.3 to 32	V
SW Pin GND Voltage	V_{SW}	-0.3 to V_{IN}+0.3	V
EN,FB,COMP,SS to GND Voltage		-0.3 to 6	V
BS to GND Voltage	V_{BS}	V_{SW}-0.3 to V_{SW}+6	V
Power Dissipation	P_D	Internally limited	mW
Operating Junction Temperature	T_J	150	℃
Storage Temperature	T_{STG}	-65 to 150	℃
Lead Temperature	T_{LEAD}	260	℃

ESD (HBM)		2000	V
MSL		Level3	
Junction to Ambient Resistance in Free Air	θ_{JA}	50	℃/W
Junction to Case Resistance in Free Air	θ_{JC}	10	℃/W

Recommended Operating Conditions

Parameter	Symbol	Min.	Max.	Unit
Input voltage	V_{IN}	4.5	30	V
Output voltage	V_{out}	0.925	28	V
Converter output current	I_{out}	0	3	A
Operating junction temperature	T_J	-40	125	℃
Operating ambient temperature	T_A	-40	85	℃

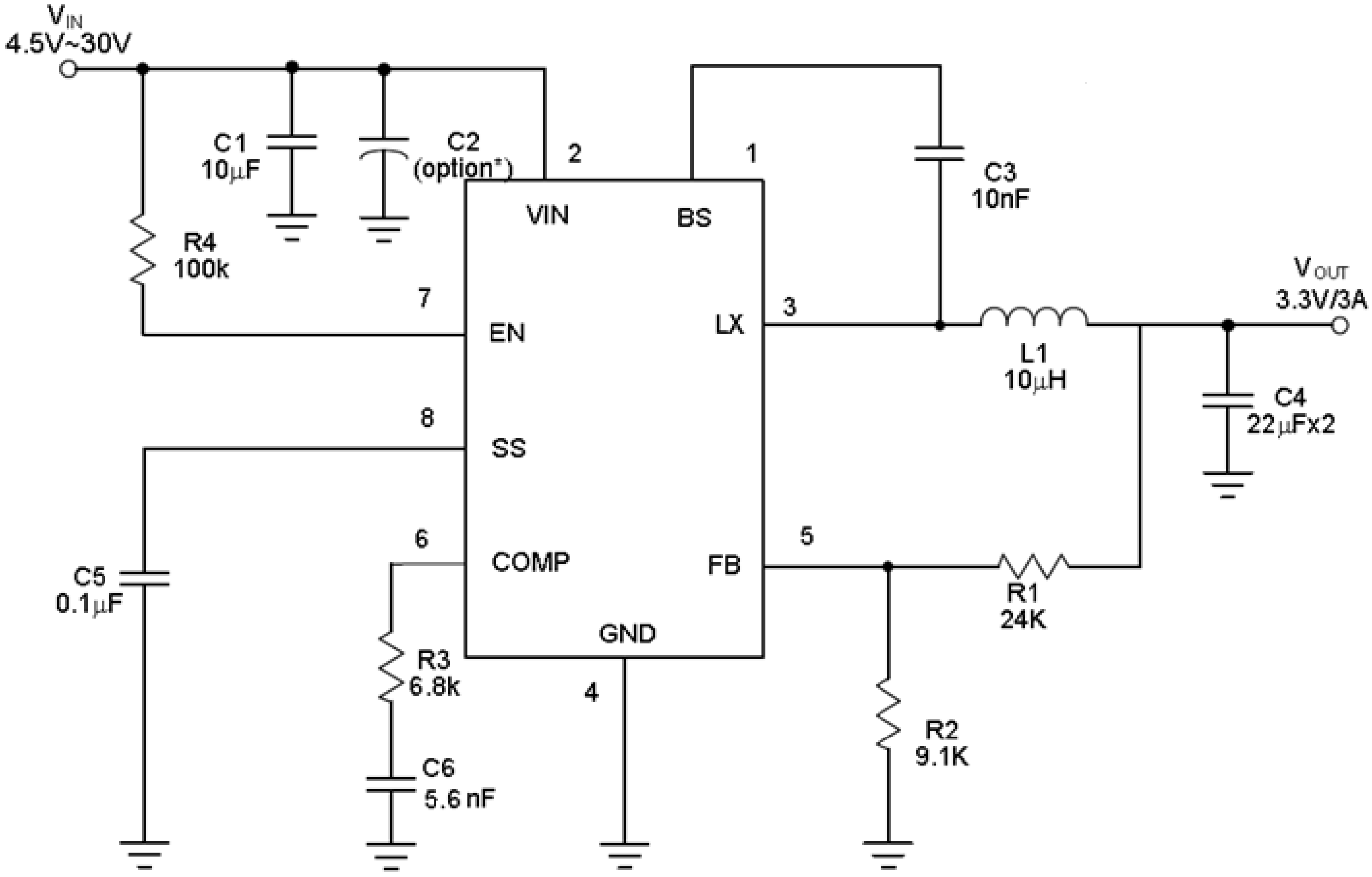
Electrical Characteristics

V_{IN} =12V, Vout=3.3V， V_{EN}=3V,TA =+25℃, unless otherwise noted

Parameter	Symbol	Condition	Min	Typ	Max	Units
SUPPLY CURRENT						
VIN Supply Current	I_{VIN}	V_{FB}=1V, V_{EN}=3V, SW=NC	-	1.9	-	mA
VIN Shutdown Supply Current	I_{VIN_SD}	V_{EN}=0V	-	0.3	-	uA
POWER-ON-RESET (POR)						
VIN POR Voltage Threshold		V_{IN} Rising	3.8	4.1	4.4	V
VIN POR Hysteresis			-	0.3	-	V
REFERENCE VOLTAGE						
Reference Voltage	V_{REF}	Regulated on FB pin	0.9	0.92	0.946	V
OSCILLATOR AND DUTY CYCLE						
Oscillator Frequency	F_{OSC}		300	340	380	kHz
Foldback Frequency		V_{FB}=0V	-	110	-	kHz
Maximum Converter's Duty			-	90	-	%
Minimum On Time			-	220	-	ns
PFM MODE OPERATION						
PFM Mode Current Limit	I_{PK_PFM}		-	0.8	-	A
PWM to PFM Inductor Peak Threshold	I_{PK_TH}		-	0.6	-	A
POWER MOSFET						
High/low Side MOSFET On Resistance			-	110	-	mΩ
High/Low Side MOSFET Leakage Current		V_{EN}=0V, V_{LX}=0V	-	-	10	uA

CURRENT-MODE PWM CONVERTER						
Error Amplifier Transconductance	Gm		-	820	-	uA/V
Error Amplifier Voltage Gain		COMP=NC	-	80	-	V/V
Switch Current to COMP Voltage Transconductance			-	5.2	-	A/V
PROTECTIONS						
High Side MOSFET Current-Limit	I_{LIM}	Peak Current	-	5.6	-	A
Over-Temperature Trip Point	T_{OTP}		-	150	-	℃
Over-Temperature Hysteresis			-	50	-	℃
Over-Voltage Protection			-	120	-	%
SOFT-START, ENABLE AND INPUT CURRENTS						
Soft-Start Current			-	6	-	uA
EN Under-Voltage Lockout (UVLO) Threshold			2.3	2.5	2.7	V
EN UVLO Hysteresis		V_{EN} rising	-	200	-	mV

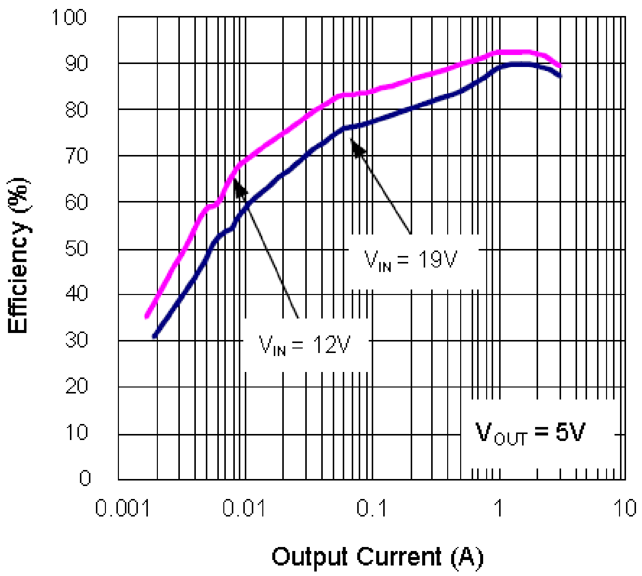
Typical Application Circuit



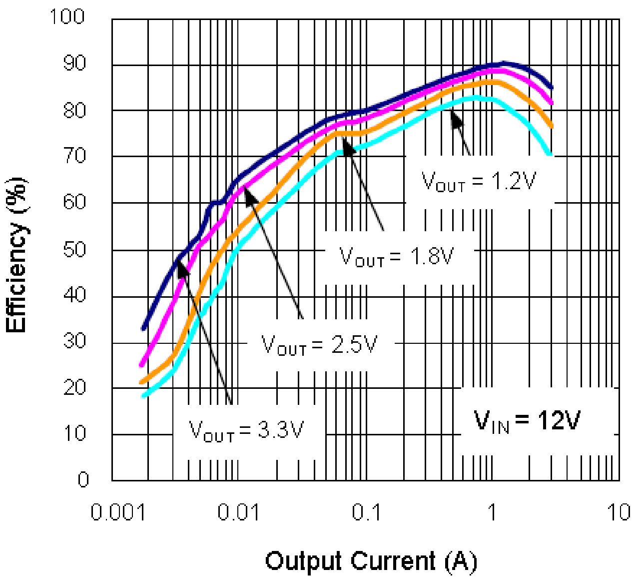
Typical Performance Characteristics

Refer to the “Typical Application Circuit” The test conditions are V_{IN}=12V, V_{OUT}=3.3V, L_1=10mH, C_2=22mF, T_A= 25° C unless otherwise specified.

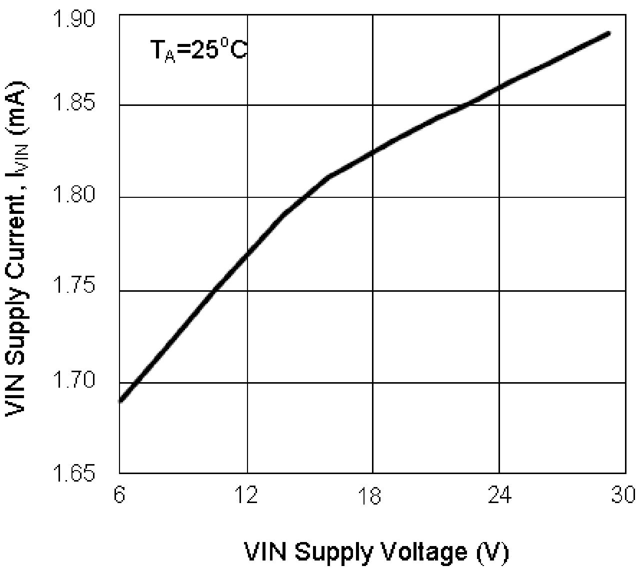
Efficiency vs. Output Current



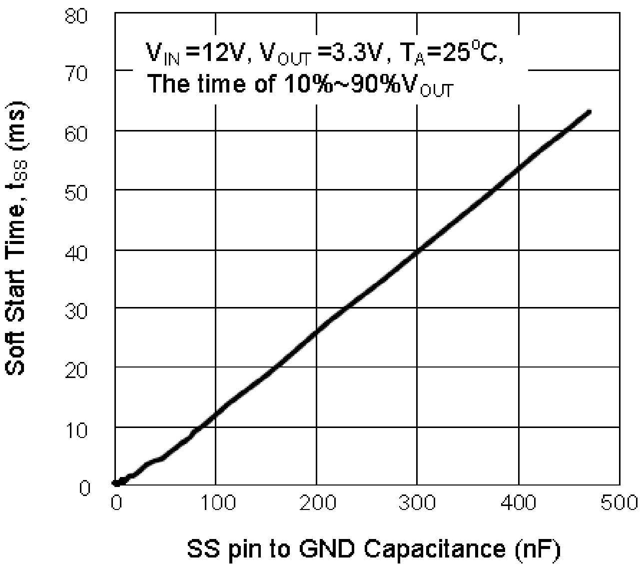
Efficiency vs. Output Current

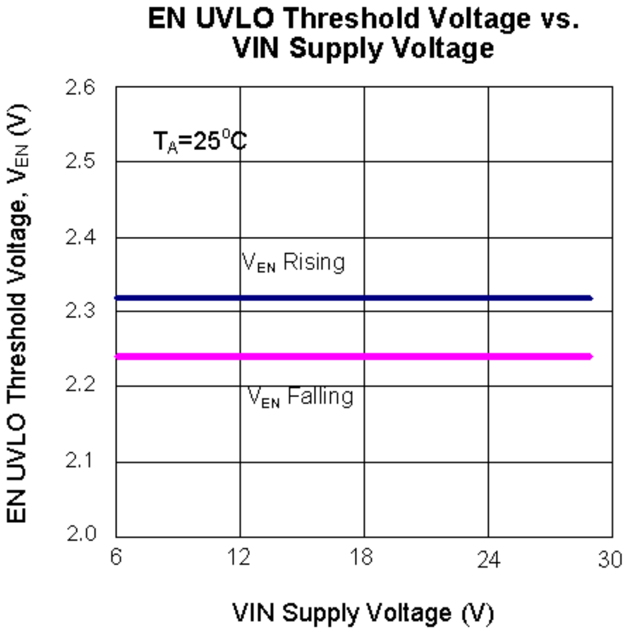


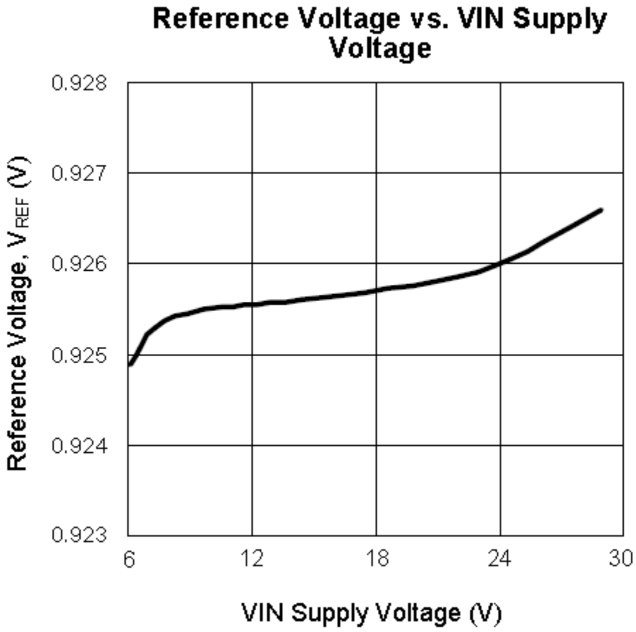
VIN Supply Current vs. VIN Supply Voltage

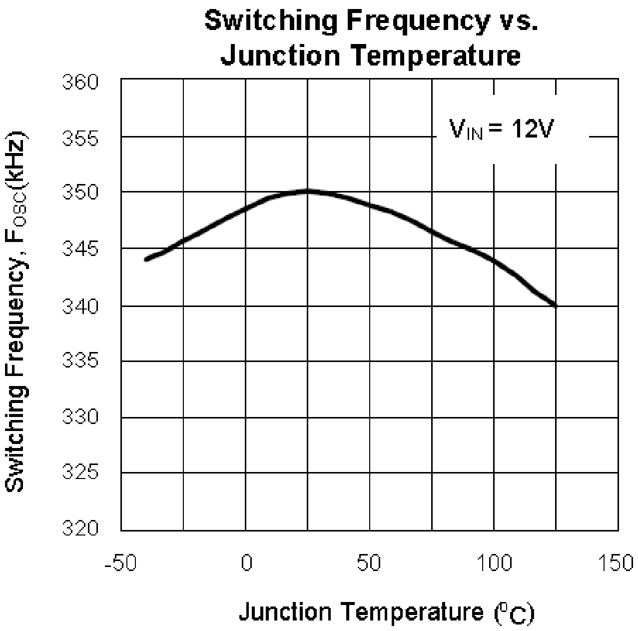


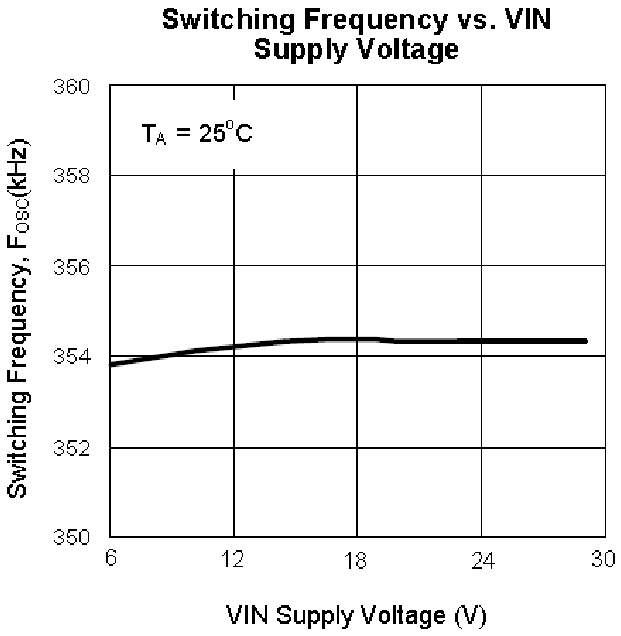
Soft Start Time vs. SS pin to GND Capacitance

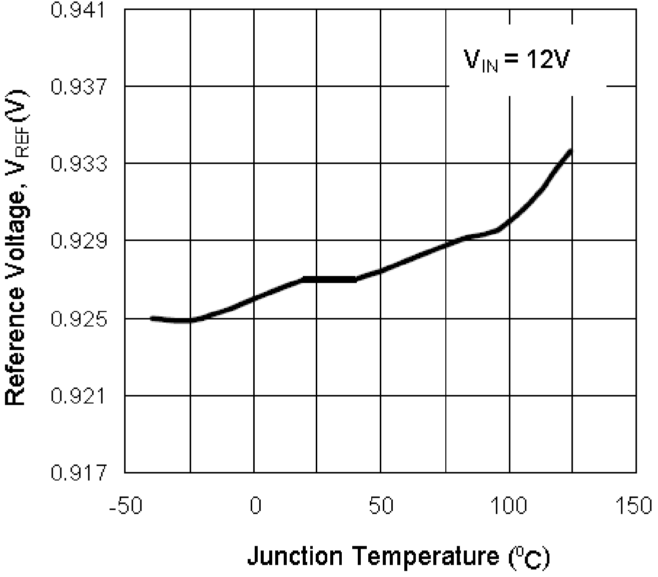



EN UVLO Threshold Voltage vs. VIN Supply Voltage

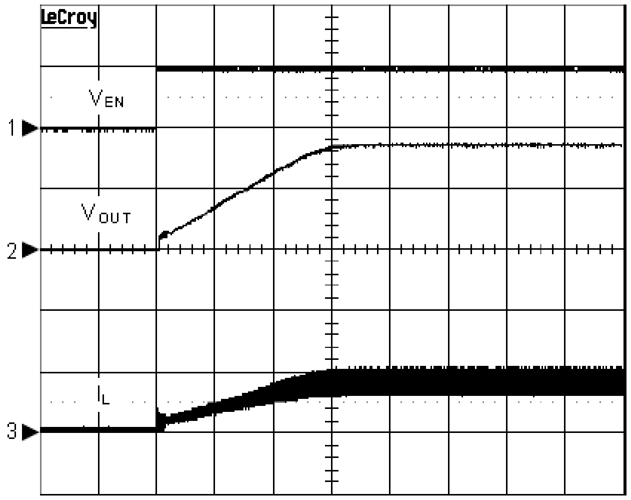

Reference Voltage vs. VIN Supply Voltage


Switching Frequency vs. Junction Temperature


Switching Frequency vs. VIN Supply Voltage



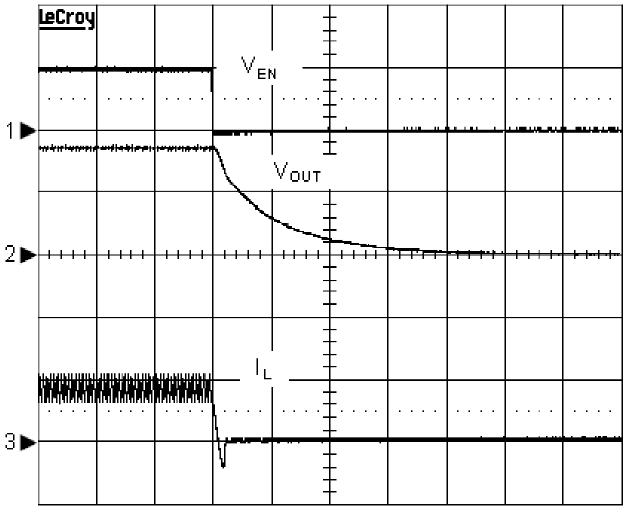
Reference Voltage vs. Junction Temperature



Enable

V_{IN} =12V, V_{OUT} =3.3V, C_{OUT} =22uF, L =10uH, R_{LOAD} =2Ω

CH1: V_{EN}, 5V/Div, DC
CH2: V_{OUT}, 2V/Div, DC
CH3: I_L, 2A/Div, DC
TIME: 5ms/Div

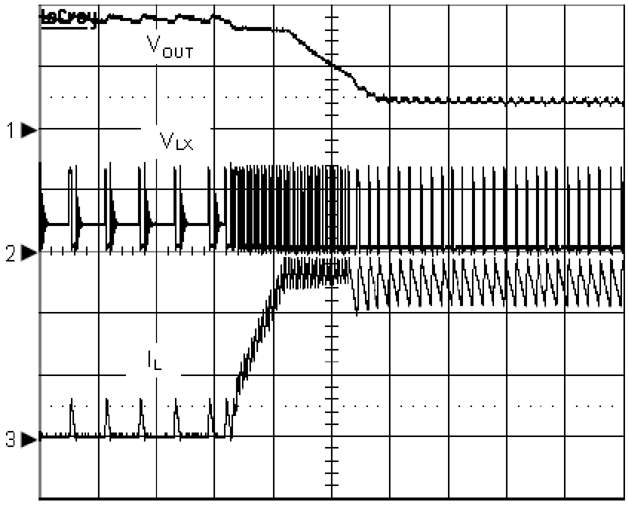


Shutdown

V_{IN} =12V, V_{OUT} =3.3V, C_{OUT} =22uF, L =10uH, R_{LOAD} =2Ω

CH1: V_{EN}, 5V/Div, DC
CH2: V_{OUT}, 2V/Div, DC
CH3: I_L, 2A/Div, DC
TIME:50μs/Div

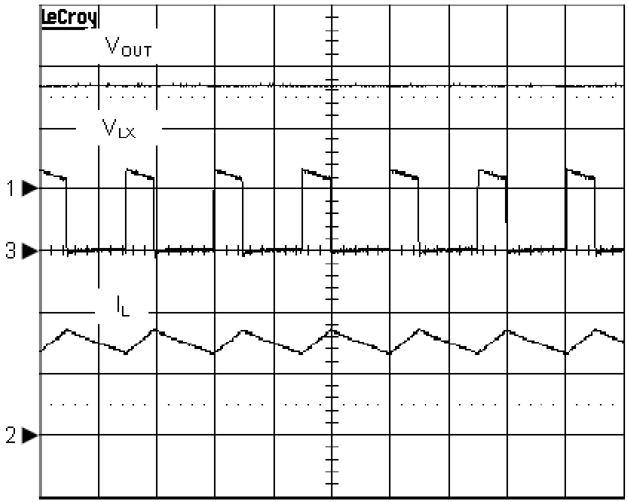
Current Limit & Frequency Foldback



V_{IN} =12V, V_{OUT} =3.3V, C_{OUT} =22uF, L =10uH, Ramp up I_{OUT} into current limit

CH1: V_{EN}, 5V/Div, DC
CH2: V_{LX}, 10V/Div, DC
CH3: I_L, 2A/Div, DC
TIME: 50μs/Div

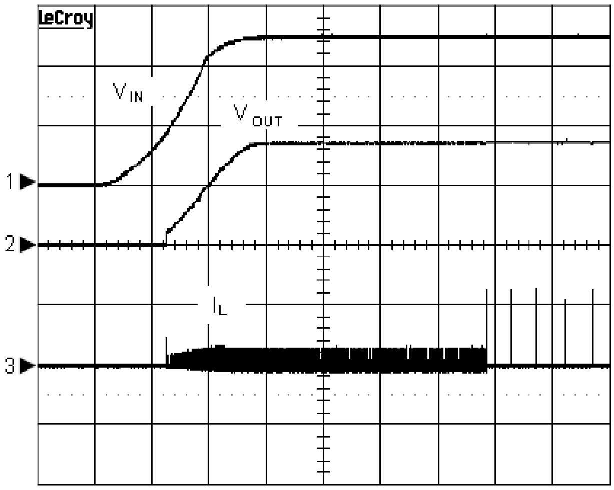
Normal Operation in Heavy Load



V_{IN} =12V, V_{OUT} =3.3V, C_{OUT} =22uF, L =10uH, I_{OUT} =3A

CH1: V_{OUT}, 2V/Div, DC
CH2: I_L, 2A/Div, DC
CH3: V_{LX}, 10V/Div, DC
TIME: 2μs/Div

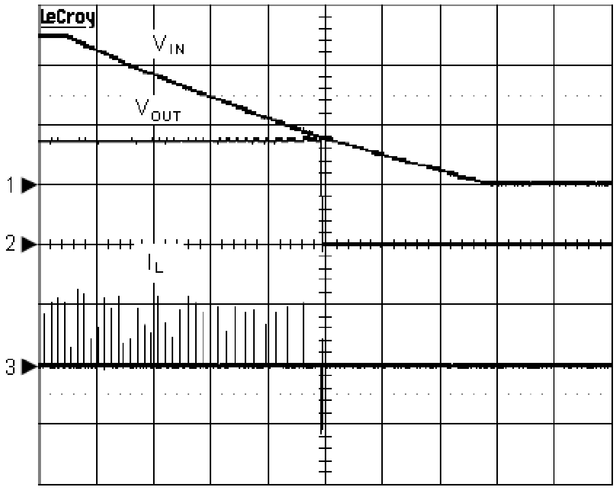
Power On



V_{IN} =12V, V_{OUT} =3.3V, C_{OUT} =22uF, L =10uH, no load

CH1: V_{IN}, 5V/Div, DC
CH2: V_{OUT}, 2V/Div, DC
CH3: I_L, 0.5A/Div, DC
TIME: 10ms/Div

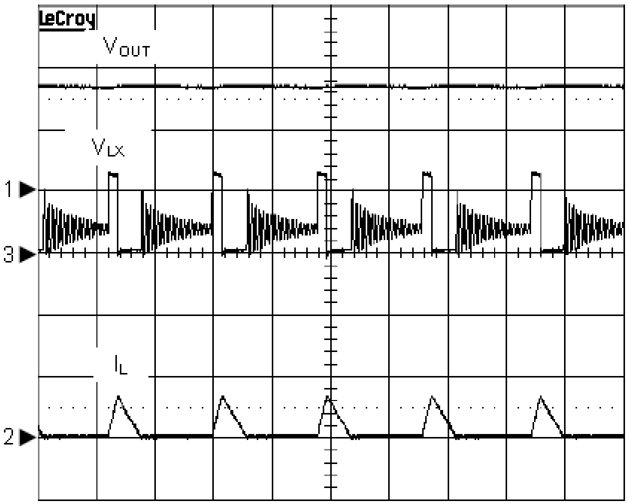
Power Off



V_{IN} =12V, V_{OUT} =3.3V, C_{OUT} =22uF, L =10uH, no load

CH1: V_{IN}, 5V/Div, DC
CH2: V_{OUT}, 2V/Div, DC
CH3: I_L, 0.5A/Div, DC
TIME: 50ms/Div

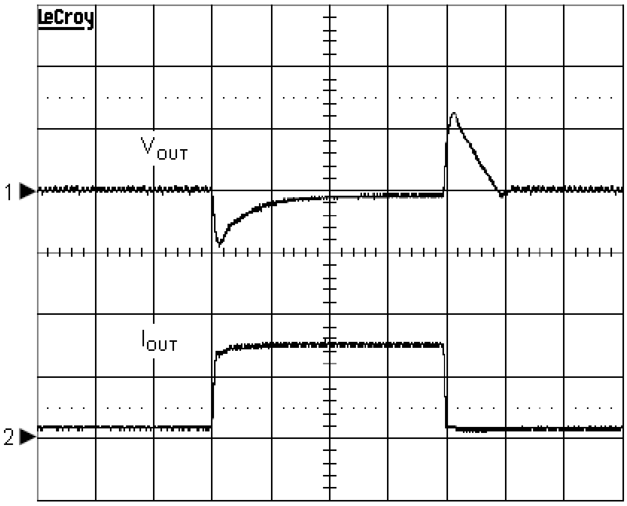
Normal Operation in Light Load



V_{IN}=12V, V_{OUT}=3.3V, C_{OUT}=22uF, L=10uH, I_{OUT}=100mA

CH1: V_{OUT}, 2V/Div, DC
CH2: I_L, 1A/Div, DC
CH3: V_{LX}, 10V/Div, DC
TIME: 5μs/Div

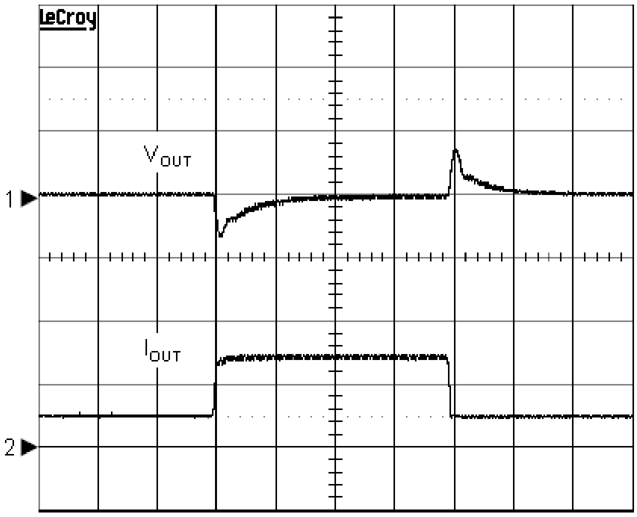
Load Transient



V_{IN}=12V, V_{OUT}=3.3V, C_{OUT}=22uF, L=10uH, COMP=6.8kΩ+3.9nF, I_{OUT}=300mA-3A-300mA

CH1: V_{OUT}, 0.5V/Div, offset=3.3V
CH2: I_{OUT}, 2A/Div, DC
TIME: 50μs/Div

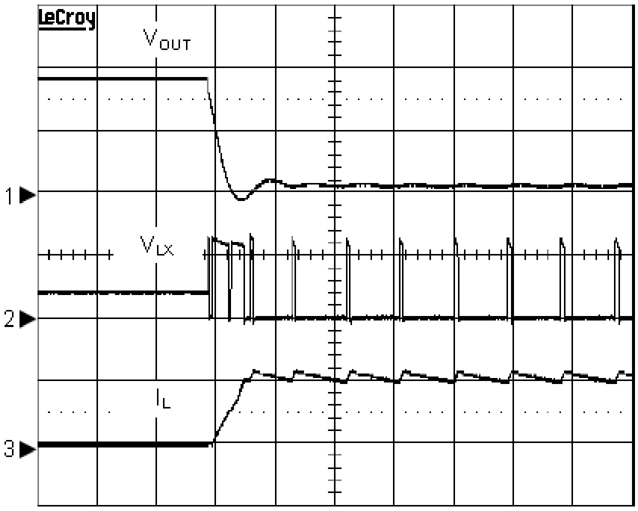
Load Transient



V_{IN}=12V, V_{OUT}=3.3V, C_{OUT}=22uF, L=10uH, COMP=6.8kΩ+3.9nF, I_{OUT}=1A-3A-1A

CH1: V_{OUT}, 0.5V/Div, offset=3.3V
CH2: I_{OUT}, 2A/Div, DC
TIME: 50μs/Div

Short Circuit



V_{IN}=12V, V_{OUT}=3.3V, C_{OUT}=22uF, L=10uH, V_{OUT} short to ground

CH1: V_{OUT}, 2V/Div, DC
CH2: V_{LX}, 10V/Div, DC
CH3: I_L, 5A/Div, DC
TIME: 10μs/Div

Function Description

Main Control Loop

The TD2786 is a constant frequency current mode switching regulator. During normal operation, the internal N-channel power MOSFET is turned on each cycle when the oscillator sets an internal RS latch and would be turned off when an internal current comparator (ICMP) resets the latch. The peak inductor current at which ICMP resets the RS latch is controlled by the voltage on the COMP pin, which is the output of the error amplifier (EAMP). An external resistive divider connected between VOUT and ground allows the EAMP to receive an output feedback voltage V_{FB} at FB pin. When the load current increases, it causes a slight decrease in V_{FB} relative to the 0.92V reference, which in turn causes the COMP volt- age to increase until the average inductor current matches the new load current.

VIN Power-On-Reset (POR) and EN

Under-voltage Lockout

The TD2786 keep monitoring the voltage on VIN pin to prevent wrong logic operations which may occur when VIN voltage is not high enough for the internal control circuitry to operate. The VIN POR has a rising threshold of 4.1V (typical) with 0.5V of hysteresis.

An external under-voltage lockout (UVLO) is sensed at the EN pin. The EN UVLO has a rising threshold of 2.5V with 0.2V of hysteresis. The EN pin should be connected a resistor divider from VIN to EN.

After the VIN and EN voltages exceed their respective voltage thresholds, the IC starts a start-up process and then ramps up the output voltage to the setting of output voltage

Over-Temperature Protection (OTP)

The over-temperature circuit limits the junction temperature of the TD2786. When the junction temperature exceeds T_J=+160° C, a thermal sensor turns off the power MOSFET, allowing the devices to cool. The thermal sensor allows the converter to start a start-up process and regulate the output voltage again after the junction temperature cools by 50° C.

The OTP is designed with a 50° C hysteresis to lower the average T_J during continuous thermal overload conditions, increasing lifetime of the IC.

Enable / Shutdown

Driving EN to ground places the TD2786 in shutdown. When in shutdown, the internal power MOSFET turns off, all internal circuitry shuts down

Current-Limit Protection

The TD2786 monitors the output current, flowing through the N-Channel power MOSFET, and limits the IC from damages during overload, short-circuit and over voltage conditions.

Frequency Foldback

The foldback frequency is controlled by the FB voltage. When the FB pin voltage is under 0.6V, the frequency of the oscillator will be reduced to 110kHz. This lower frequency allows the inductor current to safely discharge, thereby preventing current runaway. The oscillator’s frequency will switch to its designed rate when the feedback voltage on FB rises above the rising frequency foldback threshold (0.6V, typical) again

Over-Voltage Protection

The over-voltage function monitors the output voltage by FB pin. When the FB voltage increases over 120% of the reference voltage, the over-voltage protection comparator will force the low-side MOSFET gate driver high. This action actively pulls down the output voltage. As soon as the output voltage is within regulation, the OVP comparator is disengaged. The chip will restore its normal operation.

Application Information

Setting Output Voltage

The regulated output voltage is determined by:

$$VOUT = 0.925 \times (1 + \frac{R_1}{R_2})$$

To prevent stray pickup, please locate resistors R1 and R2 close to TD2786.

Inductor Capacitor Selection

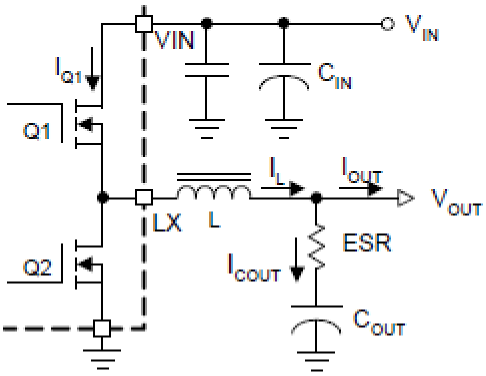
Use small ceramic capacitors for high frequency decoupling and bulk capacitors to supply the surge current needed each time the N-channel power MOSFET (Q1) turns on. Place the small ceramic capacitors physically close to the VIN and between the VIN and GND.

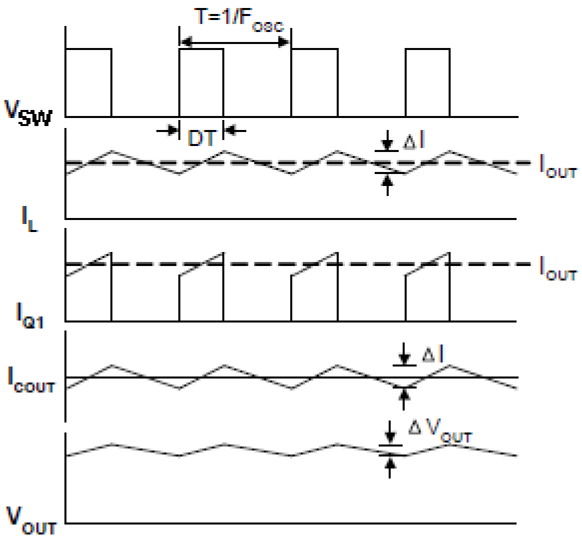
The important parameters for the bulk input capacitor are the voltage rating and the RMS current rating. For reliable operation, select the bulk capacitor with voltage and current ratings above the maximum input voltage and largest RMS current required by the circuit. The capacitor voltage rating should be at least 1.25 times greater than the maximum input voltage and a voltage rating of 1.5 times is a conservative guideline. The RMS current (IRMS) of the bulk input capacitor is calculated as the following equation:

$$I_{RMS} = I_{OUT}\sqrt{D \times (1 - D)}$$

where D is the duty cycle of the power MOSFET.

For a through hole design, several electrolytic capacitors maybe needed. For surface mount designs, solid tantalum capacitors can be used, but caution must be exercised with regard to the capacitor surge current rating.





Output Capacitor Selection

An output capacitor is required to filter the output and supply the load transient current. The filtering requirements are the function of the switching frequency and the ripple current (DI). The output ripple is the sum of the voltages, having phase shift, across the ESR and the ideal output capacitor. The peak-to-peak voltage of the ESR is calculated as the following equations:

$$D = \frac{V_{OUT}}{V_{IN}}$$

$$\Delta I = \frac{V_{OUT} \times (1 + D)}{F_{OSC} \times L}$$

$$V_{ESR} = \Delta I \times ESR$$

The peak- to-peak voltage of the ideal output capacitor is calculated as the following equations:

$$\Delta V_{COUT} = \frac{\Delta I}{8 \times F_{OSC} \times C_{OUT}}$$

For the applications using bulk capacitors, the VCOUT is much smaller than the VESR and can be ignored. Therefore the AC peak-to-peak output voltage (ΔV_{OUT}) is shown below:

$$\Delta V_{OUT} = \Delta I \times ESR$$

For the applications using bulk capacitors, the VESR is much smaller than the ΔVCOUT and can be ignored Therefore, the AC peak-to-peak output voltage(ΔVOUT) is to ΔVCOUT

Output Capacitor Selection

The load transient requirements are the function of the slew rate (di/dt) and the magnitude of the transient load current. These requirements are generally met with a mix of capacitors and careful layout. High frequency capacitors initially supply the transient and slow the current load rate seen by the bulk capacitors. The bulk filter capacitor values are generally determined by the ESR and voltage rating requirements rather than actual capacitance requirements.

High frequency decoupling capacitors should be placed as close to the power pins of the load as physically possible. Be careful not to add inductance in the circuit board wiring that could cancel the usefulness of these low inductance components. An aluminum electrolytic capacitor's ESR value is related to the case size with lower ESR available in larger case sizes. However, the Equivalent Series Inductance (ESL) of these capacitors increases with case size and can reduce the usefulness of the ca- pacitor to high slew-rate transient loading.

Table1 Capacitor Selection Guide

Vender	Model	Capacitance (µF)	TC	Voltage Rating(V)	Si2e
muRata	GRM31CR61E106K	10	X5R	25	1206
muRata	GRM31CR61C226K	22	X5R	16	1206

Inductor Value Calculation

The operating frequency and inductor selection are interrelated in that higher operating frequencies permit the use of a smaller inductor for the same amount of inductor ripple current. However, this is at the expense of efficiency due to an increase in MOSFET gate charge losses. The equation shows that the inductance value has a direct effect on ripple current.

Accepting larger values of ripple current allows the use of low inductances, but results in higher output voltage ripple and greater core losses. A reasonable starting point for setting ripple current is $\Delta I \leqslant 0.4$ x I_{OUT}(max). Please be noticed that the maximum ripple current occurs at the maximum input voltage. The minimum inductance of the inuctor is calculated by using the following equation:

$$\frac{V_{OUT} \times (V_{IN} - V_{OUT})}{340000 \times L \times V_{IN}} \leq 1.2$$

$$L \geq \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{408000 \times V_{IN}}$$

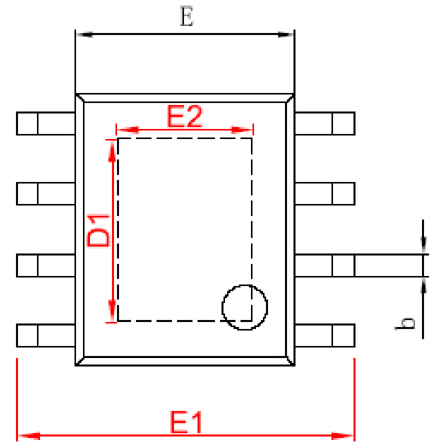
Where $V_{IN} = V_{IN(MAX)}$

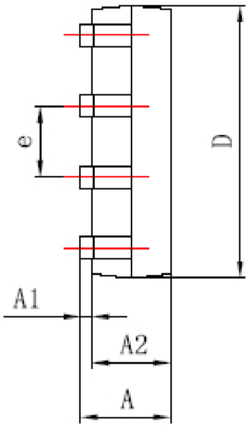
Table2 Inductor Selection Guide

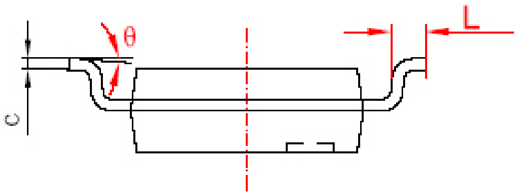
Vender	Model	Inductance (µH)	DCR (mΩ)	Current Rating(A)
CYNTEC	PCMB063T-100MS	10	62	4
Gausstek	PL94P051M-15U	15	50	3
Gausstek	PL94P051M-10U	10	38	3.8

Package Information

ESOP-8 Package Outline Dimensions







	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.350	1.750	0.053	0.069
A1	0.050	0.150	0.004	0.010
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.006	0.010
D	4.700	5.100	0.185	0.200
D1	3.202	3.402	0.126	0.134
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
E2	2.313	2.513	0.091	0.099
e	1.270(BSC)		0.050(BSC)	
L	0.400	1.270	0.016	0.050
θ	0°	8°	0°	8°

Design Notes