LM20146 Evaluation Board

查询LM20146供应商

Introduction

The LM20146 is a full-featured synchronous buck switching regulator capable of driving up to 6A of load current. The ability to adjust the operating frequency from 250kHz to 750kHz gives the designer flexibility in component selection. The LM20146 is capable of converting an input voltage between 2.95V and 5.5V down to an output voltage as low as 0.8V. Fault protection features include cycle-by-cycle current limit, output power good, and output over-voltage protection. The dual function soft-start/tracking pin can be used to control the startup response of the LM20146, and the precision enable pin can be used to easily sequence the LM20146 in sequence critical applications. The LM20146 is available in an eTSSOP-16 package with an exposed pad for enhanced thermal performance.

The LM20146 evaluation board is designed to balance overall solution size and transient response. The evaluation board measures 1.5" x 1.5" on a four layer PCB with all components placed on the top layer. The power stage and compensation components are optimized for an input voltage of 5V, but for testing purposes, the input can be varied across the entire operating range. The output voltage of the evaluation board is nominally 1.2V, but this voltage can be easily changed by replacing one of the feedback resistors (R_{FB1} or R_{FB2}). The control loop compensation of the LM20146 evaluation board is designed to provide a stable solution over the entire input voltage range with a fast transient response. The EN pin is tied to V_{IN} with a 10kΩ resistor and can be toggled directly through the enable test point
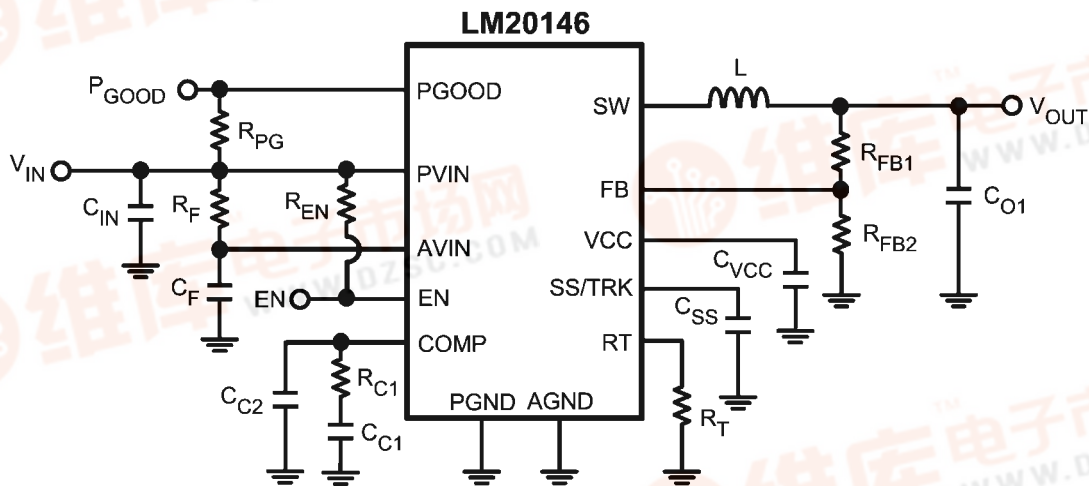

FIGURE 1. Evaluation Board Schematic

Bill of Materials

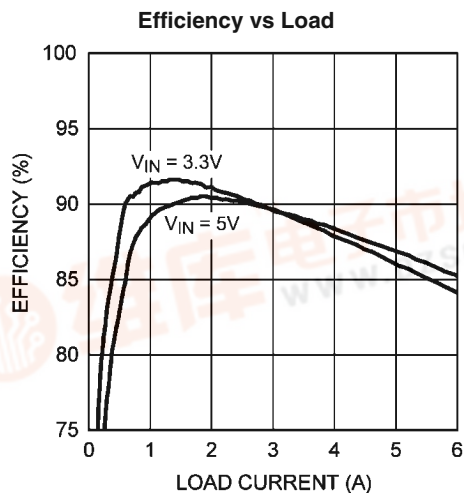| Designator	Description	Part Number	Qty	Manufacturer
U1	Synchronous Buck Regulator	LM20146MH	1	National Semiconductor
C_{IN}	100µF, 1210, X5R, 6.3V	C3225X5R0J107M	1	TDK
C_{O1}	100µF, 1210, X5R, 6.3V	C3225X5R0J107M	1	TDK
C_{O2}	OPEN	N/A	0	N/A
L	0.68µH, 5.39 mΩ, 14A Isat	SPM6530T-R68M140	1	TDK
R_F	1.0Ω, 0603	CRCW06031R0J-e3	1	Vishay-Dale
C_F	1.0µF, 0603, X5R, 6.3V	GRM188R60J105KA01	1	Murata
C_{VCC}	1.0µF, 0603, X5R, 6.3V	GRM188R60J105KA01	1	Murata
R_{PG}	10.0kΩ, 0603	CRCW06031002F-e3	1	Vishay-Dale
R_{C1}	8.25 kΩ, 0603	CRCW06038252F-e3	1	Vishay-Dale
C_{C1}	1.2nF, 0603, COG, 50V	GRM1885C1H122JA01	1	Murata
C_{C2}	OPEN	N/A	0	N/A
C_{SS}	33.0nF, 0603, X7R, 25V	VJ0603Y333KXXA	1	Vishay-Vitramon
R_{FB1}	4.99kΩ, 0603	CRCW06034991F-e3	1	Vishay-Dale
R_{FB2}	10.0kΩ, 0603	CRCW06031002F-e3	1	Vishay-Dale
R_{EN}	10.0kΩ, 0603	CRCW06031002F-e3	1	Vishay-Dale
R_T	48.7kΩ, 0603	CRCW06034872F-e3	1	Vishay-Dale
VOUT TP	Test Point	131503100	1	Tektronix
EN, PGOOD, SW, SS/RK	Test Points	52F7279	4	Keystone
P1,P2,P3,P4	POWER I/O	160-1026-02-01-00	4	Cambion

Connection Descriptions

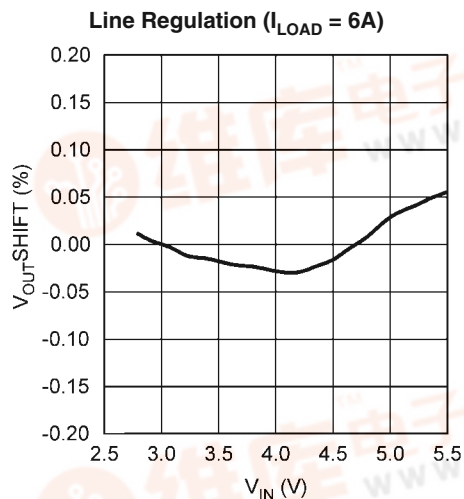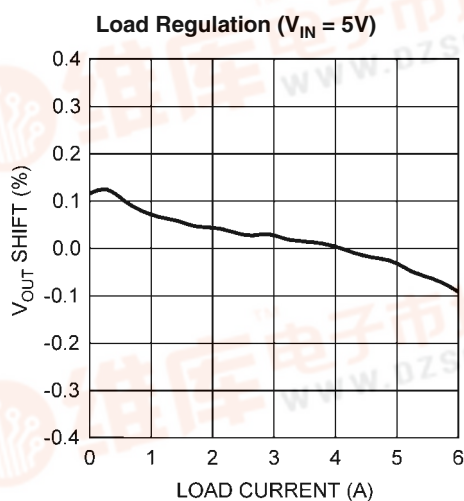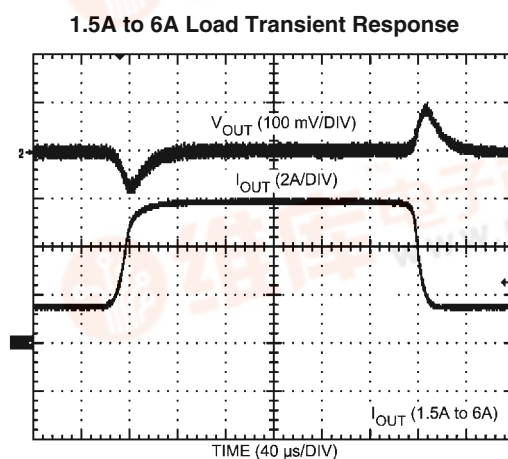| PCB Silkscreen	Description
VIN	This terminal is the input voltage to the device. The device will operate over the input voltage range of 2.95V to 5.5V. The absolute maximum voltage rating for this pin is 6V.
GND	This terminal is the ground connection to the device. There are two different GND connections on the PCB. One should be used for the input supply and the other for the load.
VOUT	This terminal connects to the output voltage of the power supply and should be connected to the load.
EN	This terminal connects to the enable pin of the device. This terminal should be connected to V_{IN} or driven externally. If driven externally, a voltage typically greater than 1.18V will enable the device. The operating voltage for this pin should not exceed 5.5V. The absolute maximum voltage rating on this pin is 6V.
SS/TRK	This terminal provides access to the SS/TRK pin of the device. Connections to this terminal are not needed for most applications. The feedback pin of the device will track the voltage on the SS/TRK pin if it is driven with an external voltage source that is below the 0.8V reference. The voltage on this pin should not exceed 5.5V during normal operation. The absolute maximum voltage rating on this pin is 6V.
PGOOD	This terminal connects to the power good output of the device. There is a 10kΩ pull-up resistor from this pin to the input voltage. The voltage on this pin should not exceed 5.5V during normal operation and has an absolute maximum voltage rating of 6V.
SW	This point allows a scope probe to be connected to observe the switch node voltage.
VOUT TP	This terminal provides an oscilloscope probe connection directly to VOUT to probe the transient response and output voltage ripple.

2

Performance Characteristics

查询LM20146供应商

Efficiency vs Load

V_{IN} = 3.3V

V_{IN} = 5V

EFFICIENCY (%)

LOAD CURRENT (A)

30079915

Line Regulation (I_{LOAD} = 6A)

V_{OUT} SHIFT (%)

V_{IN} (V)

30079916

Load Regulation (V_{IN} = 5V)

V_{OUT} SHIFT (%)

LOAD CURRENT (A)

30079917

1.5A to 6A Load Transient Response

V_{OUT} (100 mV/DIV)

I_{OUT} (2A/DIV)

I_{OUT} (1.5A to 6A)

TIME (40 μs/DIV)

30079919

Startup Waveform

V_{EN} (5V/Div) R_{LOAD} = 0.2Ω

V_{OUT} (500 mV/Div)

I_{OUT} (2A/Div)

P_{GOOD} (2A/Div)

TIME (2 ms/DIV)

30079920

www.national.com
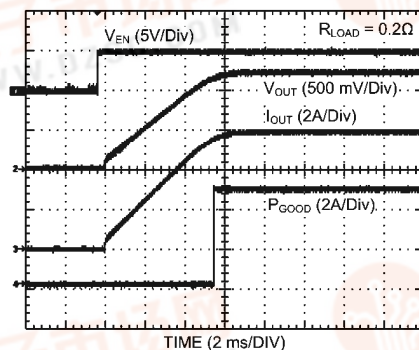
Component Selection

This section provides a walk-through of the design process for the LM20146 evaluation board. Unless otherwise indicated all formulas assume units of Amps (A) for current, Farads (F) for capacitance, Henries (H) for inductance, and Volts (V) for voltage.

INPUT CAPACITOR

The required RMS current rating of the input capacitor for a buck regulator can be estimated by the following equation:

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

The variable D refers to the duty cycle and can be approximated by:

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

From this equation, it follows that the maximum $I_{CIN(RMS)}$ requirement will occur at a full 6A load current with the system operating at 50% duty cycle. Under this condition, the maximum $I_{CIN(RMS)}$ is given by:

$$I_{CIN(RMS)} = 6A \sqrt{0.36 \times 0.64} = 2.9A$$

Ceramic capacitors feature a very large I_{RMS} rating in a small footprint, making a ceramic capacitor ideal for this application. A 100µF X5R ceramic capacitor from TDK provides the necessary input capacitance for the evaluation board.

AVIN FILTER

An RC filter should be added to prevent any switching noise on PVIN from interfering with the internal analog circuitry connected to AVIN. This can be seen on the schematic as components R_F and C_F. There is a practical limit to the value of resistor R_F as the AVIN pin will draw a short 60mA burst of current during startup. If R_F is too large the resulting voltage drop can trigger the UVLO comparator. For the evaluation board, a 1.0Ω resistor is used for R_F ensuring that UVLO will not be triggered after the part is enabled. A 1.0µF capacitor in conjunction with the 1.0Ω resistor is recommended to filter the input to AVIN.

INDUCTOR

As per the datasheet recommendations, the inductor value should initially be chosen to give a peak to peak ripple current equal to roughly 30% of the maximum output current. The peak to peak inductor ripple current can be calculated by the equation:

$$\Delta I_{P-P} = \frac{(V_{IN} - V_{OUT}) \times D}{L \times f_{SW}}$$

Rearranging this equation and solving for the inductance reveals that for this application (V_{IN} = 5V, V_{OUT} = 1.2V, f_{SW} = 750kHz, and I_{OUT} = 6A) the nominal inductance value is roughly .68 µH. This results in a peak-to-peak ripple current of 1.8A and 1.5A when the converter is operating from 5V and 3.3V respectively. Once an inductance value is calculated, an actual inductor needs to be selected based on a trade-off between physical size, efficiency, and current carrying capabil-

ity. For the LM20146 evaluation board, a TDK SPM6530T-R68M140 inductor offers a good balance between efficiency (5.39mΩ DCR), size (7.1mm x 6.5mm), and saturation current rating (14A I_{SAT}). If the output voltage of the evaluation board is increased or if the switching frequency is decreased, there is a chance the device may hit current limit at 6A output. To avoid current limit with higher output voltages the value of the inductor should be increased to reduce the ripple current.

OUTPUT CAPACITOR

The value of the output capacitor in a buck regulator influences the voltage ripple that will be present on the output voltage, as well as the large signal output voltage response to a load transient. Given the peak-to-peak inductor current ripple (ΔI_{P-P}) the output voltage ripple can be approximated by the equation:

$$\Delta V_{OUT} = \Delta I_{P-P} \times \left[R_{ESR} + \frac{1}{8 \times f_{SW} \times C_{OUT}} \right]$$

The variable R_{ESR} above refers to the Effective Series Resistance of the output capacitor. As can be seen in the above equation, the ripple voltage on the output can be divided in two parts. One part is attributed to the AC ripple current flowing through the ESR of the output capacitor. The other part is due to the AC ripple current charging and discharging the output capacitor. The output capacitor also has an affect on the amount of droop that is seen on the output voltage in response to a load transient event.

For the evaluation board, a TDK 100µF ceramic capacitor is selected for the output capacitor to provide good transient and DC performance in a relatively small package. From the technical specifications of this capacitor, the ESR is roughly 3mΩ and the effective in-circuit capacitance is approximately 60µF (reduced from 100µF due to the 1.2V DC bias and worse case tolerance). With these values, the peak to peak voltage ripple on the output when operating from a 5V input can be calculated to be about 10mV.

C_{SS}

A soft-start capacitor can be used to control the startup time of the LM20146. The startup time when using a soft-start capacitor can be estimated by the following equation:

$$t_{SS} = \frac{0.8V \times C_{SS}}{I_{SS}}$$

For the LM20146, I_{SS} is nominally 5µA. For the evaluation board, the soft-start time has been designed to be roughly 5 ms, resulting in a C_{SS} capacitor value of 33nF.

C_{VCC}

The C_{VCC} capacitor is necessary to bypass an internal 2.7V subregulator. This capacitor should be sized equal to or greater than 1µF but less than 10µF. A value of 1µF is sufficient for most applications.

C_{C1}

The capacitor C_{C1} is used to set the crossover frequency of the LM20146 control loop. Since this board was optimized to work well over the full input and output voltage range, the value of C_{C1} was selected to be 1.2nF. Once the operating conditions for the device are known, the transient response

can be optimized by reducing the value of C_{C1} and calculating the value for R_{C1} as outlined in the next section.

R_{C1}

Once the value of C_{C1} is selected, resistor R_{C1} is used to place a zero in the control loop to cancel the output filter pole. This resistor can be sized according to the equation:

$$R_{C1} = \left[\frac{C_{C1}}{C_{OUT}} \times \left[\frac{I_{OUT}}{V_{OUT}} + \frac{1 - D}{f_{SW} \times L} + \frac{D \times f_{SW}}{48750 \times V_{IN}} - \frac{1}{2 \times f_{SW} \times L} \right] \right]^{-1}$$

For stability purposes the device should be compensated for the maximum output current expected in the application.

C_{C2}

A second compensation capacitor C_{C2} can be used in some designs to provide a high frequency pole, useful for cancelling a possible zero introduced by the ESR of the output capacitor. For the LM20146 evaluation board, the C_{C2} footprint is un-populated because the low ESR ceramic capacitor used on the output does not contribute a zero to the control loop before the crossover frequency. If the ceramic capacitor on the eval-uation board is replaced with a different capacitor having significant ESR, the required value of the capacitor C_{C2} can be estimated by the equation:

$$C_{C2} = \frac{C_{OUT} \times R_{ESR}}{R_{C1}}$$

R_{FB1} and R_{FB2}

The resistors labeled R_{FB1} and R_{FB2} create a voltage divider from V_{OUT} to the feedback pin that is used to set the output of the voltage regulator. Nominally, the output of the LM20146 evaluation board is set to 1.2V, giving resistor values of $R_{FB1} = 4.99k\Omega$ and $R_{FB2} = 10.0k\Omega$. If a different output voltage is required, the value of R_{FB1} can be adjusted according to the equation:

$$R_{FB1} = \left(\frac{V_{OUT}}{0.8} - 1 \right) \times R_{FB2}$$

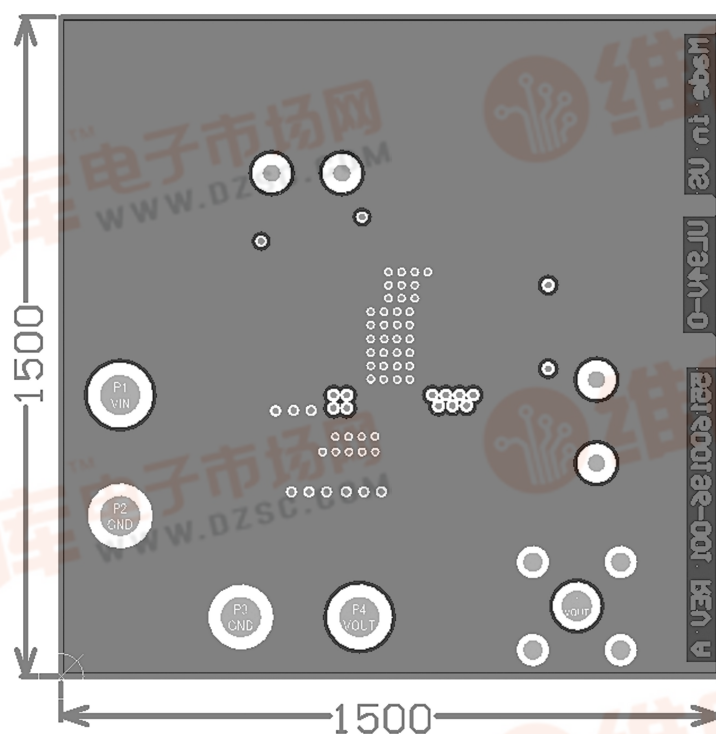R_{FB2} does not need to be changed from its value of $10.0k\Omega$.

PCB Component Placement

查询LM20146供应商

Top Layer

30079913

Mid Layer 1
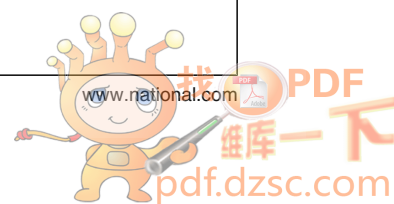
30079921
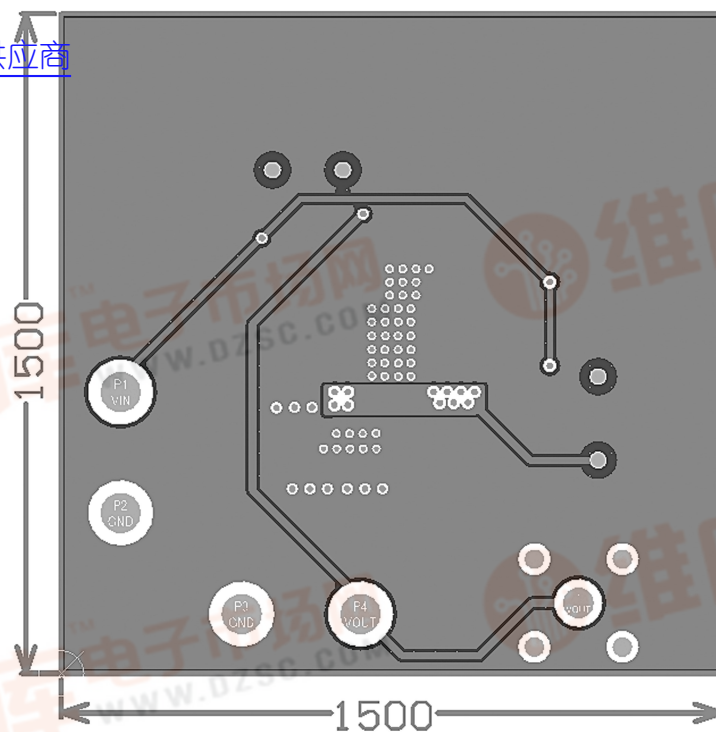
查询LM20146供应商

Mid Layer 2

30079922

Bottom Layer

30079923

Notes

查询LM20146供应商

For more National Semiconductor product information and proven design tools, visit the following Web sites at:

Products		Design Support	
Amplifiers	www.national.com/amplifiers	WEBENCH® Tools	www.national.com/webench
Audio	www.national.com/audio	App Notes	www.national.com/appnotes
Clock and Timing	www.national.com/timing	Reference Designs	www.national.com/refdesigns
Data Converters	www.national.com/adc	Samples	www.national.com/samples
Interface	www.national.com/interface	Eval Boards	www.national.com/evalboards
LVDS	www.national.com/lvds	Packaging	www.national.com/packaging
Power Management	www.national.com/power	Green Compliance	www.national.com/quality/green
Switching Regulators	www.national.com/switchers	Distributors	www.national.com/contacts
LDOs	www.national.com/ldo	Quality and Reliability	www.national.com/quality
LED Lighting	www.national.com/led	Feedback/Support	www.national.com/feedback
Voltage Reference	www.national.com/vref	Design Made Easy	www.national.com/easy
PowerWise® Solutions	www.national.com/powerwise	Solutions	www.national.com/solutions
Serial Digital Interface (SDI)	www.national.com/sdi	Mil/Aero	www.national.com/milaero
Temperature Sensors	www.national.com/tempsensors	Solar Magic®	www.national.com/solarmagic
Wireless (PLL/VCO)	www.national.com/wireless	Analog University®	www.national.com/AU

	National Semiconductor Americas Technical Support Center Email: support@nsc.com Tel: 1-800-272-9959	National Semiconductor Europe Technical Support Center Email: europe.support@nsc.com German Tel: +49 (0) 180 5010 771 English Tel: +44 (0) 870 850 4288	National Semiconductor Asia Pacific Technical Support Center Email: ap.support@nsc.com	National Semiconductor Japan Technical Support Center Email: jpn.feedback@nsc.com