SM74304 High Voltage (80V) Step Down Switching Regulator

Check for Samples: SM74304

FEATURES

- **Integrated 80V, 0.7A N-Channel Buck Switch**
- **Internal HV Vcc Regulator**
- **No Control Loop Compensation Required**
- **Ultra-Fast Transient Response**
- **On Time Varies Inversely with Line Voltage**
- **Operating Frequency Nearly Constant with Varying Line Voltage**
- **Adjustable Output Voltage**
- **Highly Efficient Operation**
- **Precision Reference**
- **Low Bias Current**
- **Intelligent Current Limit Protection**
- **Thermal Shutdown**
- **External Shutdown Control**

TYPICAL APPLICATIONS

- **Non-Isolated Buck Regulator**
- **Secondary High Voltage Post Regulator**
- **Photovoltaic Systems**

PACKAGE

- **VSSOP-8**
- **WSON-8 (4mm x 4mm)**

DESCRIPTION

The SM74304 Step Down Switching Regulator features all of the functions needed to implement low cost, efficient, Buck bias regulators. This high voltage regulator contains an 80 V, 0.7A N-Channel Buck Switch. The device is easy to apply and is provided in the VSSOP-8 and the thermally enhanced WSON-8 packages. The regulator is based on a hysteretic control scheme using an on time inversely proportional to V_{IN}. This feature allows the operating frequency to remain relatively constant with load and input voltage variations. The hysteretic control requires no control loop compensation, while providing very fast load transient response. An intelligent current limit is implemented in the SM74304 with forced off time that is inversely proportional to V_{OUT}. This current limiting scheme reduces load current foldback. Additional protection features include: Thermal Shutdown, Vcc undervoltage lockout, gate drive undervoltage lockout, and Max Duty Cycle limiter.

Connection Diagram

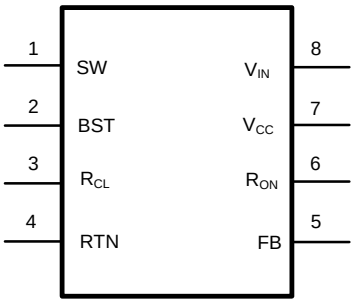


Figure 1. 8-Lead VSSOP, WSON

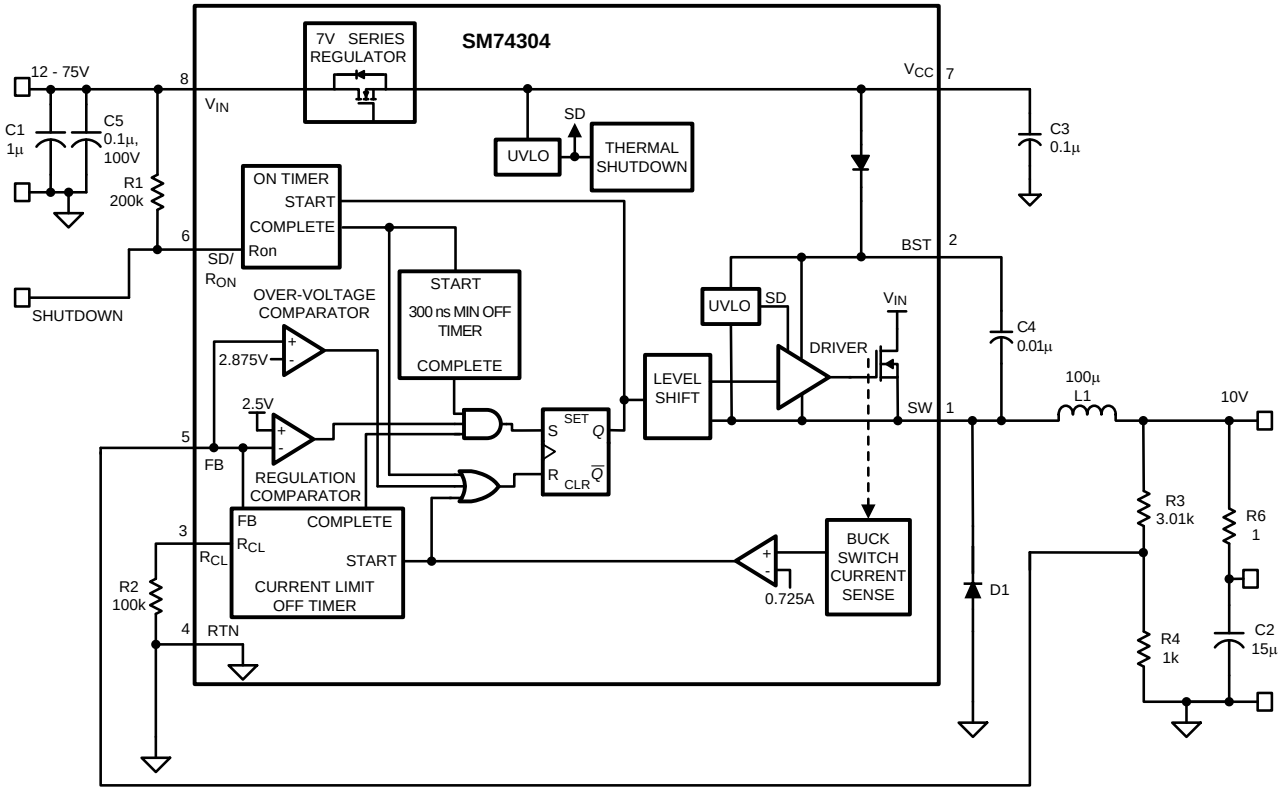
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Typical Application Circuit and Block Diagram



PIN DESCRIPTIONS

Pin	Name	Description	Application Information
1	SW	Switching Node	Power switching node. Connect to the LC output filter.
2	BST	Boost Boot–strap capacitor input	An external capacitor is required between the BST and the SW pins. A 0.01uF ceramic capacitor is recommended. An internal diode between Vcc and BST completes the Buck gate drive bias network.
3	R_{CL}	Current Limit OFF time programming pin Toff = 10^{-5} / (0.59 + (FB / 7.22 x 10^{-6} x R_{CL}))	A resistor between this pin and RTN determines the variation of off time, along with the FB pin voltage, per cycle while in current limit. The off time is preset to 17uS if FB =0V and decreases as the FB pin voltage increases.
4	RTN	Circuit Ground	
5	FB	Feedback Signal from Regulated Output	This pin is connected to the inverting input of the internal regulation comparator. The regulation threshold is 2.5V.
6	R_{ON}	On time set pin Ton = 1.42 x 10^{-10} R_{ON} / Vin	A resistor between this pin and Vin sets the switch on time as a function of Vin. The minimum recommended on time is 300ns at the maximum input voltage.
7	Vcc	Output from the internal high voltage bias regulator. V_{CC} is nominally regulated to 7 Volts	If an auxiliary voltage is available to raise the voltage on this pin, above the regulation setpoint (7V), the internal series pass regulator will shutdown, reducing the IC power dissipation. Do not exceed 14V. This output provides gate drive power for the internal Buck switch. An internal diode is provided between this pin and the BST pin. A local 0.1uF decoupling capacitor is recommended. Series pass regulator is current limited to 10mA.
8	Vin	Input supply voltage	Recommended operating range: 9V to 75V.
-	EP	Exposed PAD, underside of the WSON package option	Internally bonded to the die substrate. Connect to GND potential for low thermal impedance.

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These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

Absolute Maximum Ratings (1)(2)

V_{IN} to GND	80V
BST to GND	94V
SW to GND (Steady State)	-1V
ESD Rating (3)	
Human Body Model	2kV
Machine Model	200V
BST to V_{CC}	80V
BST to SW	14V
V_{CC} to GND	14V
All Other Inputs to GND	-0.3 to 7V
Lead Temperature (Soldering 4 sec)	260°C
Storage Temperature Range	-55°C to +150°C

(1) Absolute Maximum Ratings are limits beyond which damage to the device may occur. Operating Ratings are conditions under which operation of the device is intended to be functional. For specifications and test conditions, see the Electrical Characteristics.
(2) If Military/Aerospace specified devices are required, please contact the TI Sales Office/Distributors for availability and specifications.
(3) The human body model is a 100pF capacitor discharge through a 1.5kΩ resistor into each pin. The machine model is a 200pF capacitor discharged directly into each pin. The machine model ESD compliance level for Pin 5 is 150V. The human body ESD compliance level for Pin 7 and 8 is 1000V.

Operating Ratings (1)(2)

V_{IN}	9V to 75V
Junction Temperature	−40°C to + 125°C

(1) Absolute Maximum Ratings are limits beyond which damage to the device may occur. Operating Ratings are conditions under which operation of the device is intended to be functional. For specifications and test conditions, see the Electrical Characteristics.
(2) For detailed information on soldering plastic VSSOP and WSON packages, refer to the Packaging Data Book available from TI.

Electrical Characteristics

Specifications with standard typeface are for T_J = 25°C, and those with **boldface** type apply over full **Operating Junction Temperature range**. V_{IN} = 48V, unless otherwise stated (1).

Symbol	Parameter	Conditions	Min	Typ	Max	Units
Startup Regulator						
V_{CC} Reg	V_{CC} Regulator Output		**6.6**	7	**7.4**	V
	V_{CC} Current Limit(2)	(2)		11		mA
V_{CC} Supply						
	V_{CC} undervoltage Lockout Voltage (V_{CC} increasing)			6.3		V
	V_{CC} Undervoltage Hysteresis			206		mV
	V_{CC} UVLO Delay (filter)			3		µs
	Operating Current (ICC)	Non-Switching, FB = 3V		500	**675**	µA
	Shutdown/Standby Current	R_{ON} = 0V		100	**200**	µA

(1) All electrical characteristics having room temperature limits are tested during production with $T_A = T_J$ = 25°C. All hot and cold limits are specified by correlating the electrical characteristics to process and temperature variations and applying statistical process control.
(2) The V_{CC} output is intended as a self bias for the internal gate drive power and control circuits. Device thermal limitations limit external loading.

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Electrical Characteristics (continued)

Specifications with standard typeface are for T_J = 25°C, and those with **boldface** type apply over full **Operating Junction Temperature range**. V_{IN} = 48V, unless otherwise stated (1).

Symbol	Parameter	Conditions	Min	Typ	Max	Units
Switch Characteristics						
	Buck Switch Rds(on)	I_{TEST} = 200mA, VBST −VSW = 6.3V(3)		0.74	**1.34**	Ω
	Gate Drive UVLO (VBST – VSW)	Rising	**3.4**	4.5	**5.5**	V
	Gate Drive UVLO Hysteresis			400		mV
	Breakdown Voltage V_{IN} to Ground	T_J = 25°C T_J = -40°C to +125°C	**80** **76**			V
	Breakdown Voltage BST to V_{CC}	T_J = 25°C T_J = -40°C to +125°C	**80** **76**			V
Current Limit						
	Current Limit Threshold		**535**	725	**900**	mA
	Current Limit Response Time	I_{switch} Overdrive = 0.1A Time to Switch Off		225		ns
	OFF time generator (test 1)	FB=0V, RCL = 100K		17		µs
	OFF time generator (test 2)	FB=2.3V, RCL = 100K		2.65		µs
On Time Generator						
	TON -1	Vin = 10V Ron = 200K	**2.15**	2.77	**3.5**	µs
	TON -2	Vin = 75V Ron = 200K	**290**	390	**490**	ns
	Remote Shutdown Threshold	Rising	**0.45**	0.7	**1.1**	V
	Remote Shutdown Hysteresis			40		mV
Minimum Off Time						
	Minimum Off Timer	FB = 0V		300		ns
Regulation and OV Comparators						
	FB Reference Threshold	Internal reference Trip point for switch ON	**2.445**	2.5	**2.550**	V
	FB Over-Voltage Threshold	Trip point for switch OFF		2.875		V
	FB Bias Current			100		nA
Thermal Shutdown						
Tsd	Thermal Shutdown Temp.			165		°C
	Thermal Shutdown Hysteresis			25		°C
Thermal Resistance						
θ_{JA}	Junction to Ambient	DGK0008A Package		200		°C/W
		NGT0008A Package		40		°C/W

(3) For devices procurred in the WSON-8 package the Rds(on) limits are specified by design characterization data only.

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Detailed Operating Description

The SM74304 Step Down Switching Regulator features all of the functions needed to implement low cost, efficient, Buck bias regulators. This high voltage regulator contains an 80V, 0.7A N-Channel Buck Switch. The device is easy to apply and is provided in the VSSOP-8 and the thermally enhanced WSON-8 packages. The regulator is based on a hysteretic control scheme using an on time inversely proportional to Vin. This feature allows the operating frequency to remain relatively constant with load and input voltage variations. The hysteretic control requires no control loop compensation, while providing very fast load transient response. An intelligent current limit scheme is implemented in the SM74304 with forced off time, after current limit detection, which is inversely proportional to Vout. This current limiting scheme reduces load current foldback. Additional protection features include: Thermal Shutdown, Vcc undervoltage lockout, Gate drive undervoltage lockout and Max Duty Cycle limiter. The SM74304 can be applied in numerous applications to efficiently regulate step down higher voltage inputs. This regulator is well suited for photovoltaic electronics, 48 Volt Telecom, and the new 42V Automotive power bus ranges.

Hysteretic Control Circuit Overview

The SM74304 is a Buck DC-DC regulator that uses an on time control scheme. The on time is programmed by an external resistor and varies inversely with line input voltage (Vin). The core regulation elements of the SM74304 are the feedback comparator and the on time one-shot. The regulator output voltage is sensed at the feedback pin (FB) and is compared to an internal reference voltage (2.5V). If the FB signal is below the reference voltage, the buck switch is turned on for a fixed time pulse determined by the line voltage and a programming resistor (R_{ON}). Following the on period the switch will remain off for at least the minimum off timer period of 300ns. If the FB pin voltage is still below the reference after the 300ns off time, the switch will turn on again for another on time period. This switching behavior will continue until the FB pin voltage reaches the reference voltage level.

The SM74304 operates in discontinuous conduction mode at light load currents or continuous conduction mode at heavier load currents. In discontinuous conduction mode, current through the output inductor starts at zero and ramps up to a peak value during the buck switch on time and then back to zero during the off time. The inductor current remains at zero until the next on time period starts when FB falls below the internal reference. In discontinuous mode the operating frequency can be relatively low and will vary with load. Therefore at light loads the conversion efficiency is maintained, since the switching losses decrease with the reduction in load current and switching frequency. The approximate discontinuous mode operating frequency can be calculated as follows:

$$F = \frac{V_{OUT}^2 \times L}{1 \times 10^{-20} \times R_{Load} \times (R_{ON})^2} \quad (1)$$

In continuous conduction mode, current flows continuously through the inductor and never ramps down to zero. In this mode the operating frequency is greater than the discontinuous mode frequency and remains relatively constant with load and line variations. The approximate continuous mode operating frequency can be calculated as follows:

$$F = \frac{V_{OUT}}{1.42 \times 10^{-10} \times R_{ON}} \quad (2)$$

The output voltage (Vout) can be programmed by two external resistors as shown in Figure 2. The regulation point can be calculated as follows:

$$V_{OUT} = 2.5 \times \left(\frac{(R1 + R2)}{R2} \right) \quad (3)$$

The feedback comparator in hysteretic regulators depend upon the output ripple voltage to switch the output transistor on and off at regular intervals. In order for the internal comparator to respond quickly to changes in output voltage, proportional to inductor current, a minimum amount of capacitor Equivalent Series Resistance (ESR) is required. A ripple voltage of 25mV to 50mV is recommended at the feedback pin (FB) for stable operation. In cases where the intrinsic capacitor ESR is too small, additional series resistance may be added.

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For applications where lower output voltage ripple is required the load can be connected directly to the low ESR output capacitor, as shown in Figure 2. The series resistor (R) will degrade the load regulation. Another technique for enhancing the ripple voltage at the FB pin is to place a capacitor in parallel with the feedback divider resistor R1. The addition of the capacitor reduces the attenuation of the ripple voltage from the feedback divider

High Voltage Bias Regulator

The SM74304 contains an internal high voltage bias regulator. The input pin (Vin) can be connected directly to line voltages from 9 to 75 Volts. To avoid supply voltage transients due to long lead inductances on the input pin (Vin Pin 8), it is always recommended to connect low ESR ceramic chip capacitor (≅ 0.1µF) between "Vin" pin and "RTN" pin (pin 4), located close to SM74304. The regulator is internally current limited to 10mA. Upon power up, the regulator is enabled and sources current into an external capacitor connected to the Vcc pin. When the voltage on the Vcc pin reaches the regulation point of 7V, the controller output is enabled.

An external auxiliary supply voltage can be applied to the Vcc pin. If the auxiliary voltage is greater than 7 Volts the internal regulator will essentially shutoff, thus reducing internal power dissipation.

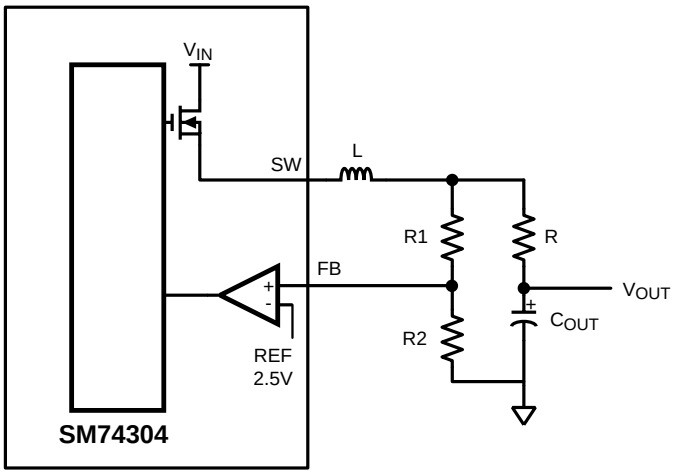


Figure 2. Low Ripple Output Configuration

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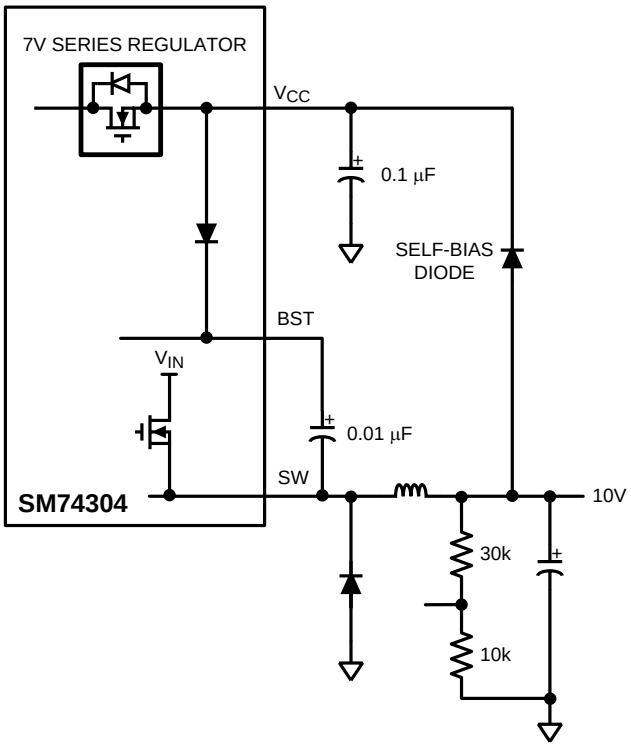


Figure 3. Self Biased Configuration

Over-Voltage Comparator

The over-voltage comparator is provided to protect the output from overvoltage conditions due to sudden input line voltage changes or output loading changes. The over-voltage comparator monitors the FB pin versus an internal 2.875V reference (OV_REF). If the voltage at FB rises above OV_REF the comparator immediately terminates the buck switch on time pulse.

ON Time generator and Shutdown

The on time of the SM74304 is set inversely proportional to the input voltage by an external resistor connected between Ron and Vin. The Ron terminal is a low impedance input biased at approximately 1.5V. Thus the current through the resistor and into the Ron terminal is approximately proportional to Vin and used internally to control the on timer. This scheme of input voltage feed-forward hysteretic operation achieves nearly constant operational frequency over varying line and load conditions. The on time equation for the SM74304 is :

$$Ton = 1.42 \times 10^{-10} \times R_{ON} / V_{IN} \quad (4)$$

The R_{ON} pin of the SM74304 also provides a shutdown function which disables the regulator and significantly decreases quiescent power dissipation. By pulling the R_{ON} pin to below 0.7V logic threshold activates the low power shutdown mode. The V_{IN} quiescent current in the shutdown mode is approximately 100µA internal to the SM74304 plus the current in the R_{ON} resistor.

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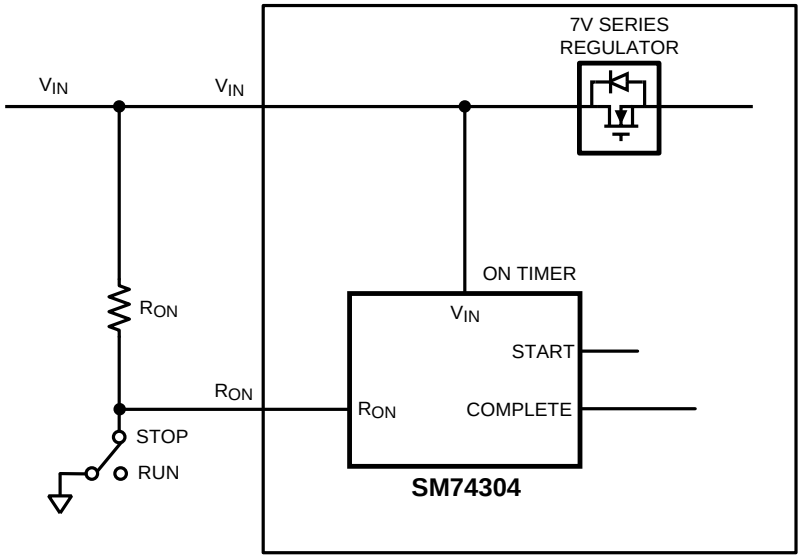


Figure 4. Shutdown Implementation

Current Limit

The SM74304 contains an intelligent current limit off timer intended to reduce the foldback characteristic inherent with fixed off-time over-current protection. If the current in the Buck switch exceeds 725mA the present cycle on time is immediately terminated (cycle by cycle current limit). Following the termination of the cycle a non-resetable current limit off timer is initiated. The duration of the off time is a function of the external resistor (R_{CL}) and the FB pin voltage. When the FB pin voltage equals zero, the current limit off time is internally preset to 17uS. This condition occurs in short circuit operation when a maximum amount of off time is required.

In cases of overload (not complete short circuit) the current limit off time can be reduced as a function of the output voltage (measured at the FB pin). Reducing the off time with smaller overloads reduces the amount of foldback and also reduces the initial start-up time. The current limit off time for a given FB pin voltage and R_{CL} resistor can be calculated by the following equation:

$$T_{OFF} = \frac{10^{-5}}{0.59 + \frac{V_{FB}}{\left(7.22 \times 10^{-6} \times R_{CL}\right)}} \quad (5)$$

Applications utilizing low resistance inductors and/or a low voltage drop rectifier may require special evaluation at high line, short circuit conditions. In this special case the preset 17uS (FB = 0V) off time may be insufficient to balance the inductor volt*time product. Additional inductor resistance, output resistance or a larger voltage drop rectifier may be necessary to balance the inductor cycle volt*time product and limit the short circuit current.

N - Channel Buck Switch and Driver

The SM74304 integrates an N-Channel Buck switch and associated floating high voltage gate driver. This gate driver circuit works in conjunction with an external bootstrap capacitor and an internal high voltage diode. The bootstrap capacitor is charged by V_{CC} through the internal high voltage diode. A 0.01uF ceramic capacitor connected between the BST pin and SW pin is recommended.

During each cycle when the Buck switch turns off, the SW pin is approximately 0V. When the SW pin voltage is low, the bootstrap capacitor will be charged from Vcc through the internal diode. The minimum off timer, set to 300ns, ensures that there will be a minimum interval every cycle to recharge the bootstrap capacitor.

An external re-circulating diode from the SW pin to ground is necessary to carry the inductor current after the internal Buck switch turns off. This external diode must be of the Ultra-fast or Schottky type to reduce turn-on losses and current over-shoot. The reverse voltage rating of the re-circulating diode must be greater than the maximum line input voltage.

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Thermal Protection

Internal Thermal Shutdown circuitry is provided to protect the integrated circuit in the event the maximum junction temperature is exceeded. When thermal protection is activated, typically at 165 degrees Celsius, the controller is forced into a low power reset state, disabling the output driver. This feature is provided to prevent catastrophic failures from accidental device overheating.

Minimum Load Current

A minimum load current of 1 mA is required to maintain proper operation. If the load current falls below that level, the bootstrap capacitor may discharge during the long off-time, and the circuit will either shutdown, or cycle on and off at a low frequency. If the load current is expected to drop below 1 mA in the application, the feedback resistors should be chosen low enough in value so they provide the minimum required current at nominal Vout.

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TYPICAL CHARACTERISTICS

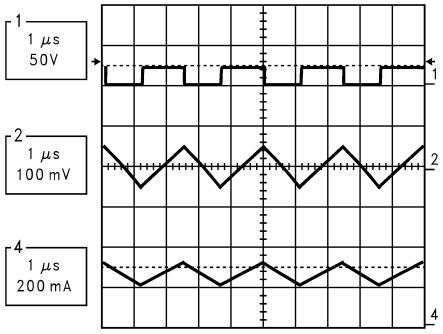


Figure 5. Operational Waveforms
SM74304 Operation: V_{OUT} = 10V, V_{IN} = 20V, I_{OUT} = 250mA,
CH1: Switch Node, CH2: V_{OUT} (AC), CH4: Inductor Current

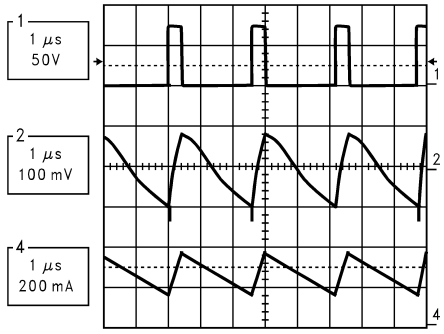


Figure 6. Operational Waveforms
SM74304 Operation: V_{OUT} = 10V, V_{IN} = 75V, I_{OUT} = 250mA,
CH1: Switch Node, CH2: V_{OUT} (AC), CH4: Inductor Current

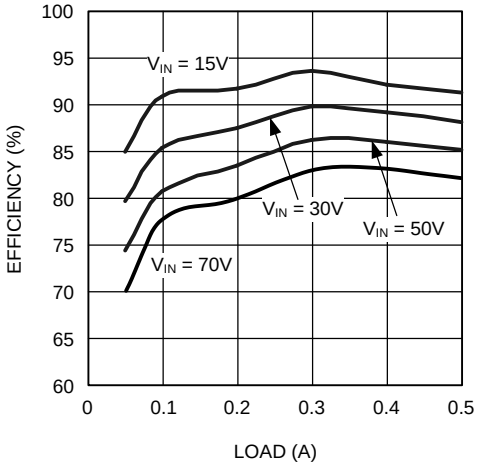


Figure 7. SM74304 10V Output Efficiency

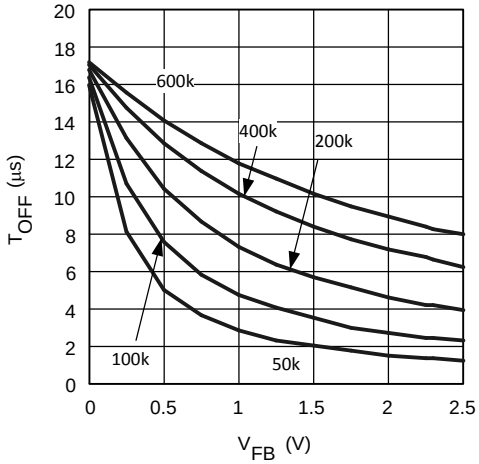


Figure 8. Current Limit V_{FB} vs T_{OFF}
R_{CL} = 50k -600k

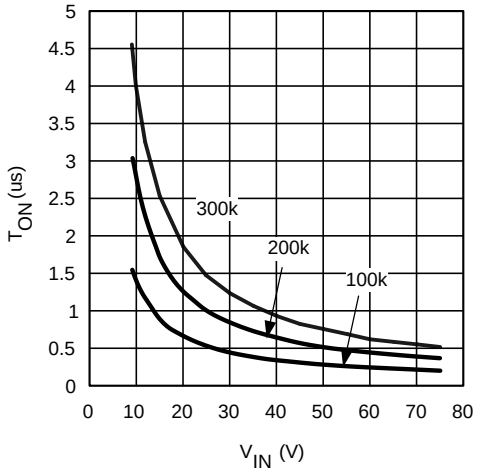


Figure 9. V_{IN} vs T_{ON}
R_{ON} = 100k, 200k, 300k

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Table 1. 10V, 400mA Design Bill of Materials

ITEM	PART NUMBER	DESCRIPTION	VALUE
C1	C4532X7R2A105M	CAPACITOR, CER, TDK	1µ, 100V
C2	C4532X7R1E156M	CAPACITOR, CER, TDK	15µ, 25V
C3	C1206C104K5RAC	CAPACITOR, CER, KEMET	0.1µ, 50V
C4	C1206C103K5RAC	CAPACITOR, CER, KEMET	0.01µ, 50V
C5	C3216X7R2A104KT	CAPACITOR, CER, TDK	0.1µ, 100V
D1	MURA110T3	DIODE, 100V, ON SEMI	
L1	SLF7045T-101MR60-1	BUCK INDUCTOR, TDK	100µH
R1	CRCW12062003F	RESISTOR	200K
R2	CRCW12061003F	RESISTOR	100K
R3	CRCW12063011F	RESISTOR	3.01K
R4	CRCW12061001F	RESISTOR	1K
R5	CRCW12061R00F	RESISTOR	1
U1	SM74304	REGULATOR, TI	

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REVISION HISTORY

Changes from Original (April 2013) to Revision A	Page
• Changed layout of National Data Sheet to TI format	11

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