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1A, 2.2MHz, Synchronous Step-Down Regulator

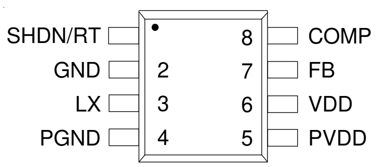
General Description

The RT8030 is a high efficiency synchronous, step-down DC/DC converter. Its input voltage range is from 2.6V to 5.5V and provides an adjustable regulated output voltage from 0.8V to 5V while delivering output current up to 1A.

The internal synchronous low on-resistance power switches increase efficiency and eliminate the need for an external Schottky diode. Switching frequency is set by an external resistor or can be synchronized to an external clock. 100% duty cycle provides low dropout operation extending battery life in portable systems. Current mode operation with external compensation allows the transient response to be optimized over a wide range of loads and output capacitors.

RT8030 operation in forced continuous PWM Mode which minimizes ripple voltage and reduces the noise and RF interference. 100% duty cycle in Low Dropout Operation further maximize battery life.

Pin Configurations



SOP-8

Features

- **High Efficiency : Up to 95%**
- **Low $R_{DS(ON)}$ Internal Switches : 160mΩ**
- **Programmable Frequency : 300kHz to 2.5MHz**
- **No Schottky Diode Required**
- **0.8V Reference Allows Low Output Voltage**
- **Forced Continuous Mode Operation**
- **Low Dropout Operation : 100% Duty Cycle**
- **RoHS Compliant and Halogen Free**

Applications

- Portable Instruments
- Battery-Powered Equipment
- Notebook Computers
- Distributed Power Systems
- IP Phones
- Digital Cameras

Ordering Information

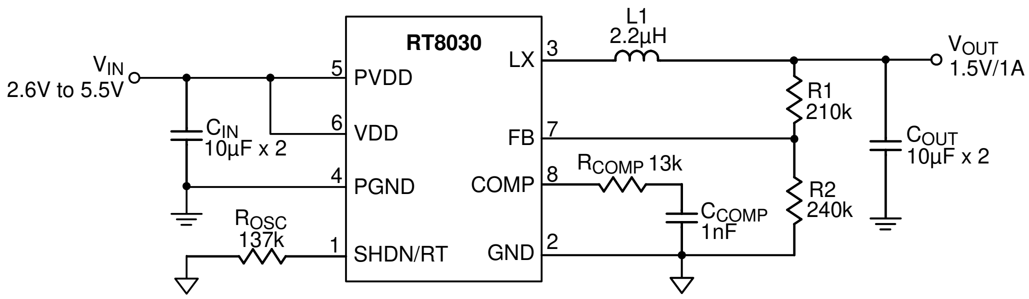
RT8030□□
- Package Type
  S : SOP-8
- Lead Plating System
  G : Green (Halogen Free and Pb Free)

Note :

Richtek products are :

- RoHS compliant and compatible with the current requirements of IPC/JEDEC J-STD-020.
- Suitable for use in SnPb or Pb-free soldering processes.

Typical Application Circuit

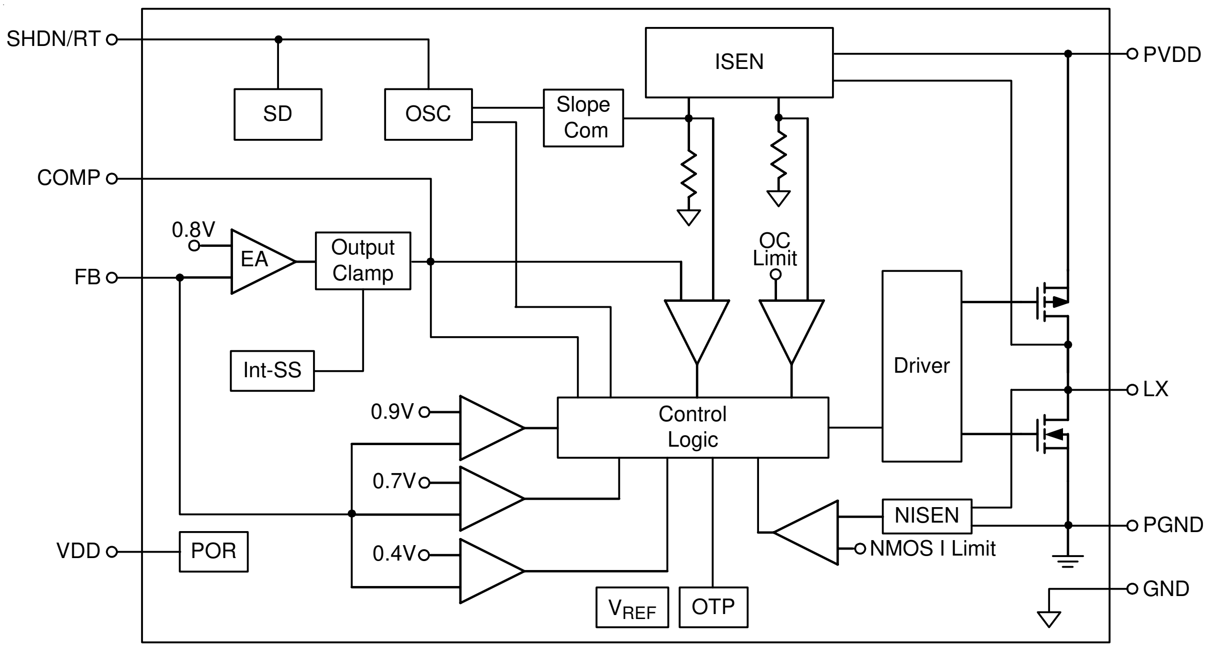


Note : Using all Ceramic Capacitors

Functional Pin Description

Pin No.	Pin Name	Pin Function
1	SHDN/RT	Oscillator Resistor Input. Connecting a resistor to ground from this pin sets the switching frequency. Forcing this pin to V_{DD} causes the device to be shut down.
2	GND	Signal Ground. All small-signal components and compensation components should connect to this ground, which in turn connects to PGND at one point.
3	LX	Internal Power MOSFET Switches Output. Connect this pin to the inductor.
4	PGND	Power Ground. Connect this pin close to the (−) terminal of C_{IN} and C_{OUT}.
5	PVDD	Power Input Supply. Decouple this pin to PGND with a capacitor.
6	VDD	Signal Input Supply. Decouple this pin to GND with a capacitor. Normally V_{DD} is equal to PVDD.
7	FB	Feedback Pin. Receives the feedback voltage from a resistive divider connected across the output.
8	COMP	Error Amplifier Compensation Point. The current comparator threshold increases with this control voltage. Connect external compensation elements to this pin to stabilize the control loop.

Function Block Diagram



Operation

Main Control Loop

The RT8030 is a monolithic, constant-frequency, current mode step-down DC/DC converter. During normal operation, the internal top power switch (P-MOSFET) is turned on at the beginning of each clock cycle. Current in the inductor increases until the peak inductor current reach the value defined by the voltage on the COMP pin. The error amplifier adjusts the voltage on the COMP pin by comparing the feedback signal from a resistor divider on the FB pin with an internal 0.8V reference. When the load current increases, it causes a reduction in the feedback voltage relative to the reference. The error amplifier raises the COMP voltage until the average inductor current matches the new load current. When the top power MOSFET shuts off, the synchronous power switch (N-MOSFET) turns on until either the bottom current limit is reached or the beginning of the next clock cycle.

The operating frequency is set by an external resistor connected between the RT pin and ground. The practical switching frequency can range from 300kHz to 2.5MHz.

Dropout Operation

When the input supply voltage decreases toward the output voltage, the duty cycle increases toward the maximum on-time. Further reduction of the supply voltage forces the main switch to remain on for more than one cycle eventually reaching 100% duty cycle.

The output voltage will then be determined by the input voltage minus the voltage drop across the internal P-MOSFET and the inductor.

Low Supply Operation

The RT8030 is designed to operate down to an input supply voltage of 2.6V. One important consideration at low input supply voltages is that the $R_{DS(ON)}$ of the P-Channel and N-Channel power switches increases. The user should calculate the power dissipation when the RT8030 is used at 100% duty cycle with low input voltages to ensure that thermal limits are not exceeded.

Slope Compensation and Inductor Peak Current

Slope compensation provides stability in constant frequency architectures by preventing sub-harmonic oscillations at duty cycles greater than 50%. It is accomplished internally by adding a compensating ramp to the inductor current signal. Normally, the maximum inductor peak current is reduced when slope compensation is added. In the RT8030, however, separated inductor current signals are used to monitor over current condition. This keeps the maximum output current relatively constant regardless of duty cycle.

Short Circuit Protection

When the output is shorted to ground, the inductor current decays very slowly during a single switching cycle. A current runaway detector is used to monitor inductor current. As current increasing beyond the control of current loop, switching cycles will be skipped to prevent current runaway from occurring.

Absolute Maximum Ratings (Note 1)

- Supply Input Voltage, V_{DD}, P_{VDD} ---------- –0.3V to 6V
- LX Pin Switch Voltage ---------- –0.3V to (PVDD + 0.3V)
- Other I/O Pin Voltages ---------- –0.3V to (VDD + 0.3V)
- LX Pin Switch Current ---------- 4A
- Power Dissipation, P_D @ T_A = 25°C
  SOP-8 ---------- 0.909W
- Package Thermal Resistance (Note 2)
  SOP-8, θ_{JA} ---------- 110°C/W
- Junction Temperature ---------- 150°C
- Lead Temperature (Soldering, 10 sec.) ---------- 260°C
- Storage Temperature Range ---------- –65°C to 150°C
- ESD Susceptibility (Note 3)
  HBM (Human Body Mode) ---------- 2kV
  MM (Machine Mode) ---------- 200V

Recommended Operating Conditions (Note 4)

- Input Voltage Range, V_{DD} ---------- 2.6V to 5.5V
- Junction Temperature Range ---------- –40°C to 125°C
- Ambient Temperature Range ---------- –40°C to 85°C

Electrical Characteristics

(V_{DD} = 3.3V, T_A = 25°C, unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Feedback Reference Voltage	V_{REF}		0.784	0.8	0.816	V
DC Bias Current		Active, V_{FB} = 0.78V, Not Switching	--	460	--	μA
		Shutdown	--	--	1	μA
Output Voltage Line Regulation		V_{IN} = 2.7V to 5.5V	--	0.04	--	%/V
Output Voltage Load Regulation		0A < I_{LOAD} < 1A	--	0.25	--	%
Error Amplifier Transconductance	g_m		--	800	--	μS
Current Sense Transresistance	R_T		--	0.4	--	Ω
Switching Frequency		R_{OSC} = 332k	0.8	1	1.2	MHz
		Switching Frequency	0.3	--	2.5	MHz
Switch On Resistance, High	R_{PMOS}	I_{SW} = 0.5A	--	150	--	mΩ
Switch On Resistance, Low	R_{NMOS}	I_{SW} = 0.5A	--	160	--	mΩ
Peak Current Limit	I_{LIM}		2.2	3.2	--	A
Under Voltage Lockout Threshold		VDD Rising	--	2.4	--	V
		VDD Falling	--	2.3	--	V
Shutdown Threshold	$V_{SHDN/RT}$		--	V_{IN} – 0.7	V_{IN} – 0.4	V

Note 1. Stresses listed as the above "Absolute Maximum Ratings" may cause permanent damage to the device. These are for stress ratings. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may remain possibility to affect device reliability.

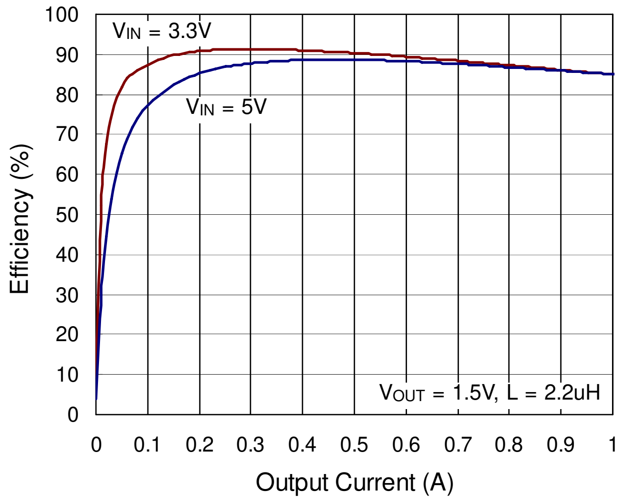
Note 2. θ_{JA} is measured in the natural convection at T_A = 25°C on 4-layers high effective thermal conductivity test board of JEDEC 51-7 thermal measurement standard.

Note 3. Devices are ESD sensitive. Handling precaution is recommended.

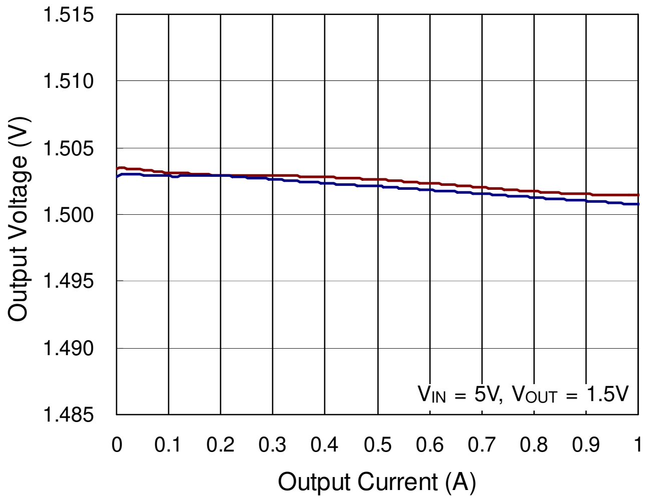
Note 4. The device is not guaranteed to function outside its operating conditions.

Typical Operating Characteristics

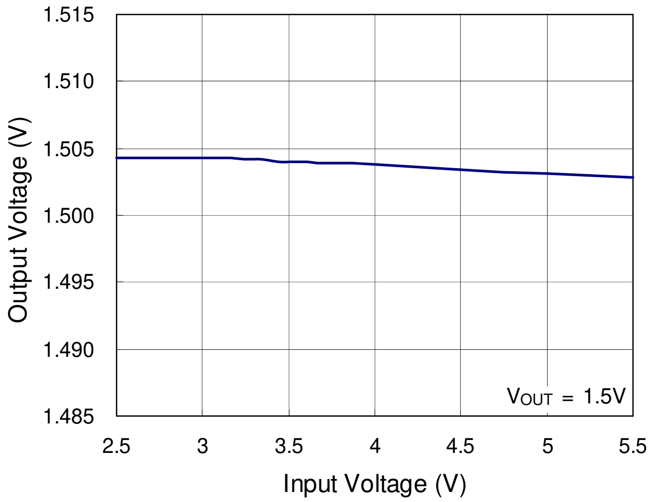
Efficiency vs. Output Current



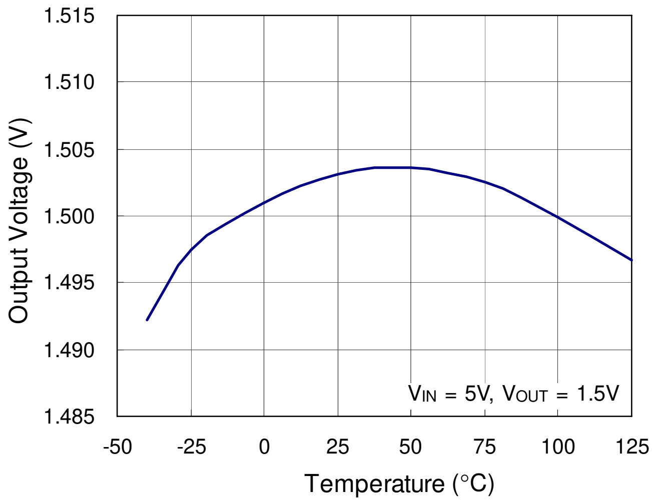
Output Voltage vs. Output Current



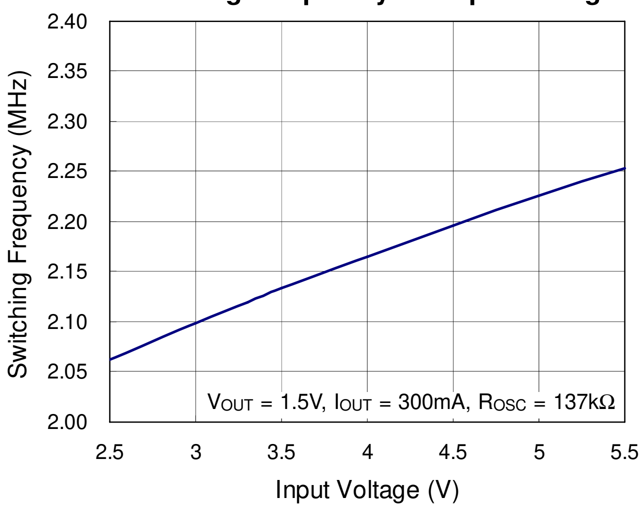
Output Voltage vs. Input Voltage



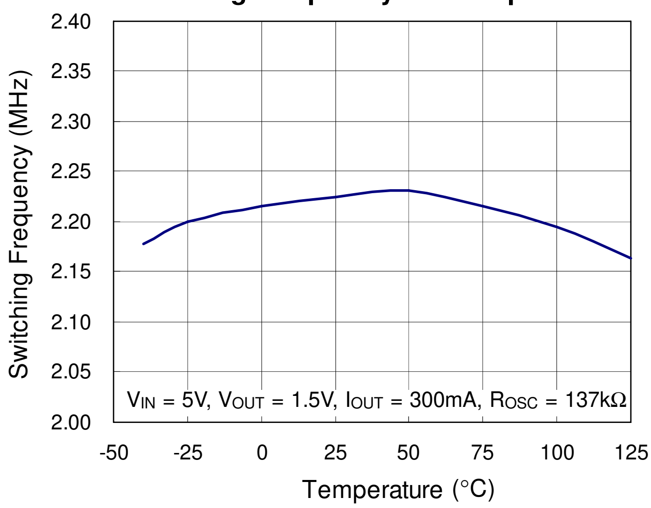
Output Voltage vs. Temperature

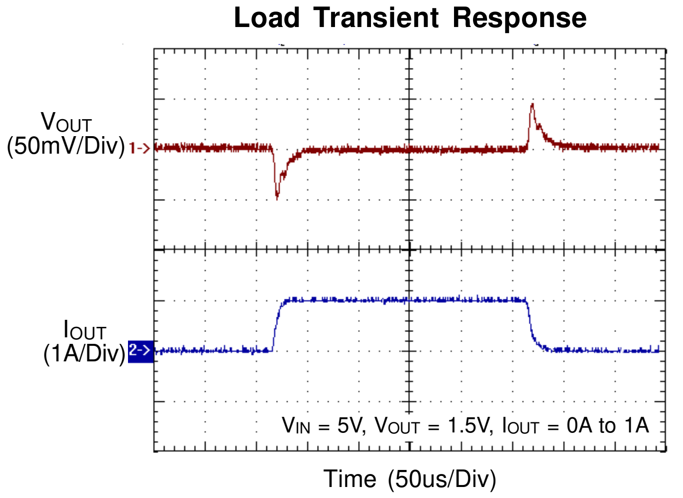


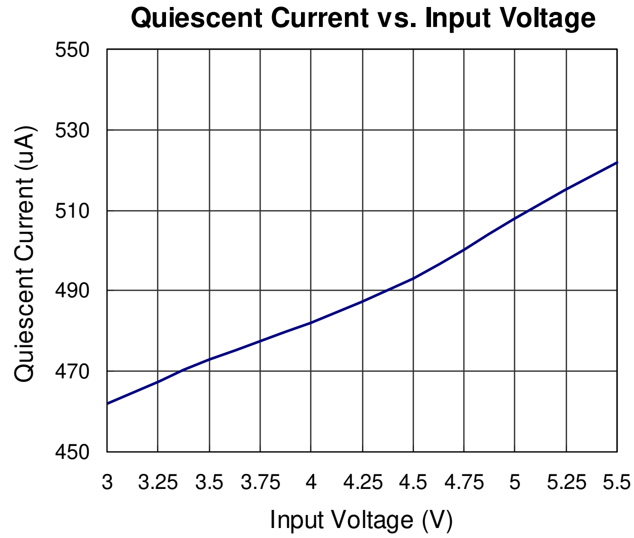
Switching Frequency vs. Input Voltage

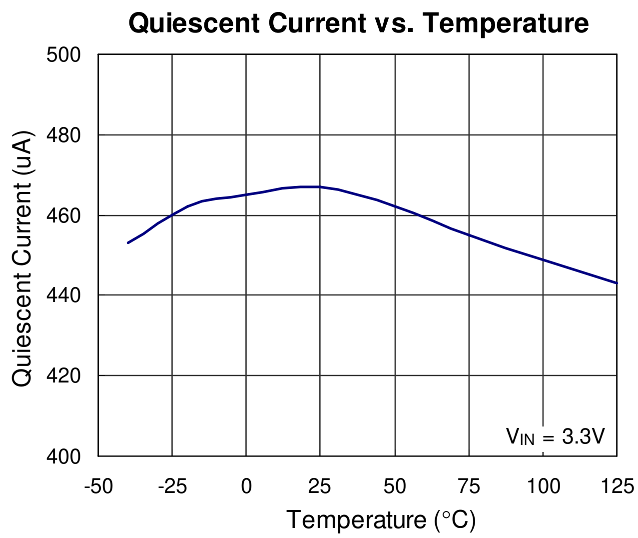


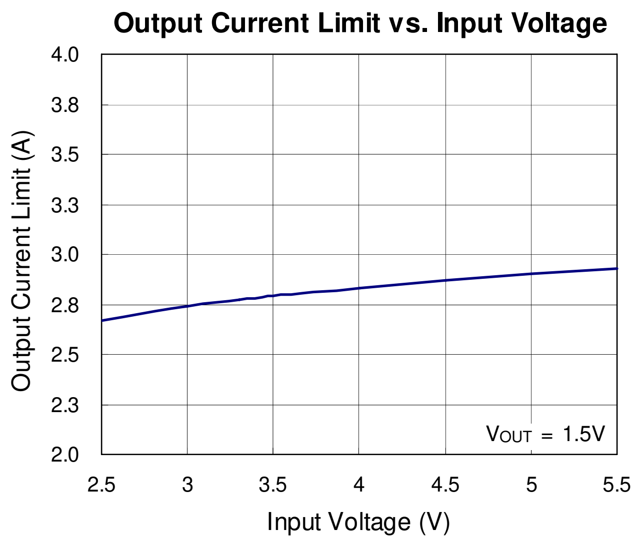
Switching Frequency vs. Temperature

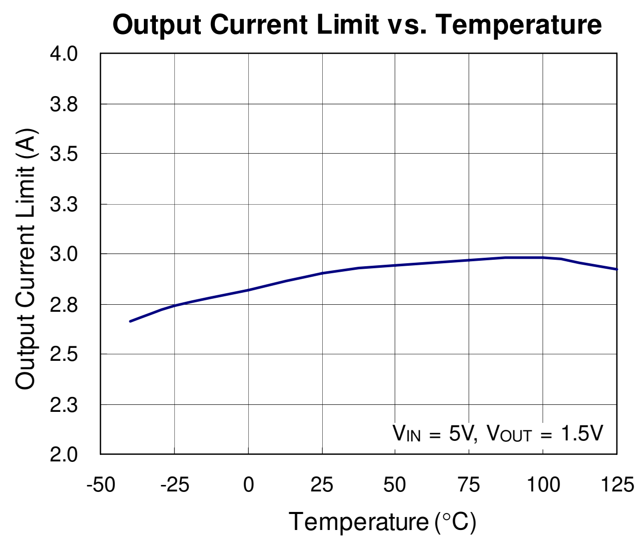


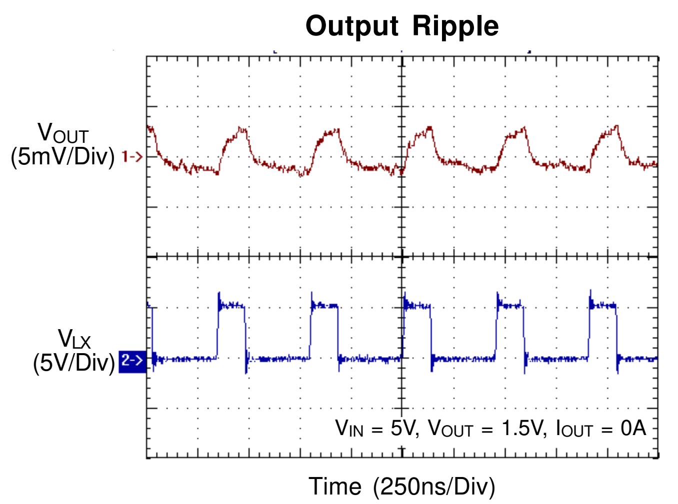

Load Transient Response
VOUT (50mV/Div)
IOUT (1A/Div)
VIN = 5V, VOUT = 1.5V, IOUT = 0A to 1A
Time (50us/Div)

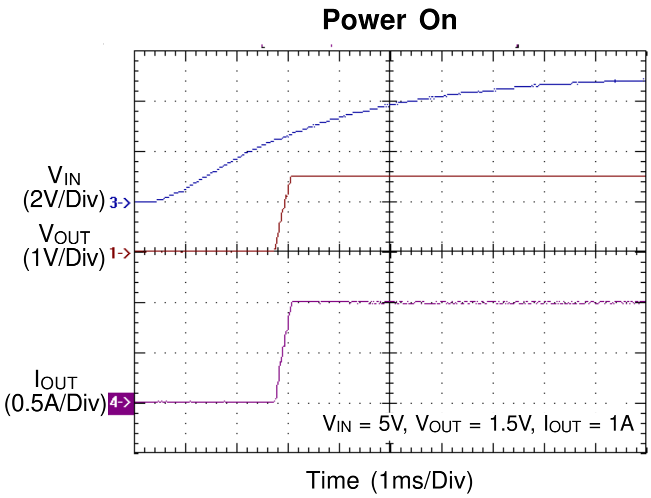

Quiescent Current vs. Input Voltage
Quiescent Current (uA)
550
530
510
490
470
450
3
3.25
3.5
3.75
4
4.25
4.5
4.75
5
5.25
5.5
Input Voltage (V)

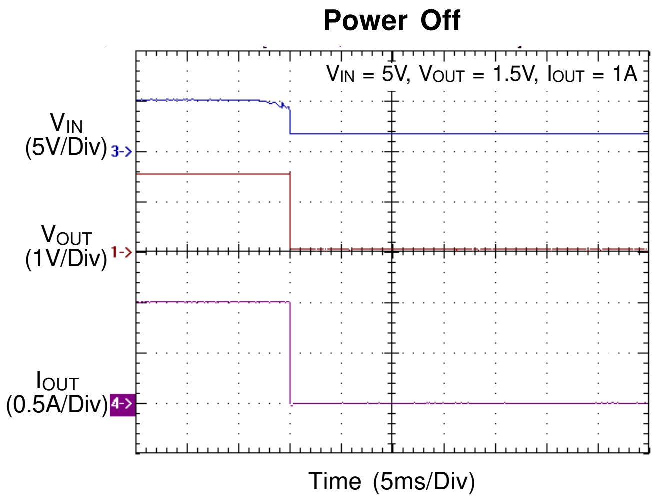

Quiescent Current vs. Temperature
Quiescent Current (uA)
500
480
460
440
420
400
-50
-25
0
25
50
75
100
125
VIN = 3.3V
Temperature (°C)


Output Current Limit vs. Input Voltage
Output Current Limit (A)
4.0
3.8
3.5
3.3
3.0
2.8
2.5
2.3
2.0
2.5
3
3.5
4
4.5
5
5.5
VOUT = 1.5V
Input Voltage (V)


Output Current Limit vs. Temperature
Output Current Limit (A)
4.0
3.8
3.5
3.3
3.0
2.8
2.5
2.3
2.0
-50
-25
0
25
50
75
100
125
VIN = 5V, VOUT = 1.5V
Temperature (°C)


Output Ripple
VOUT (5mV/Div)
VLX (5V/Div)
VIN = 5V, VOUT = 1.5V, IOUT = 0A
Time (250ns/Div)


Power On
VIN
(2V/Div)
VOUT
(1V/Div)
IOUT
(0.5A/Div)
VIN = 5V, VOUT = 1.5V, IOUT = 1A
Time (1ms/Div)


Power Off
VIN = 5V, VOUT = 1.5V, IOUT = 1A
VIN
(5V/Div)
VOUT
(1V/Div)
IOUT
(0.5A/Div)
Time (5ms/Div)

Application Information

The basic RT8030 application circuit is shown in Typical Application Circuit. External component selection is determined by the maximum load current and begins with the selection of the inductor value and operating frequency followed by C_{IN} and C_{OUT}.

Operating Frequency

Selection of the operating frequency is a tradeoff between efficiency and component size. High frequency operation allows the use of smaller inductor and capacitor values. Operation at lower frequency improves efficiency by reducing internal gate charge and switching losses but requires larger inductance and/or capacitance to maintain low output ripple voltage.

The operating frequency of the RT8030 is determined by an external resistor that is connected between the RT pin and ground. The value of the resistor sets the ramp current that is used to charge and discharge an internal timing capacitor within the oscillator. The R_{OSC} resistor value can be determined by examining the frequency vs. R_{OSC} curve. Although frequencies as high as 2.5MHz are possible, the minimum on-time of the RT8030 imposes a minimum limit on the operating duty cycle. The minimum on-time is typically 110ns. Therefore, the minimum duty cycle is equal to 100 x 110ns x f(Hz).

Inductor Selection

For a given input and output voltage, the inductor value and operating frequency determine the ripple current. The ripple current ΔI_L increases with higher V_{IN} and decreases with higher inductance.

$$\Delta I_L = \left[\frac{V_{OUT}}{f \times L}\right]\left[1 - \frac{V_{OUT}}{V_{IN}}\right]$$

Having a lower ripple current reduces the ESR losses in the output capacitors and the output voltage ripple. Highest efficiency operation is achieved at low frequency with small ripple current. This, however, requires a large inductor. A reasonable starting point for selecting the ripple current is $\Delta I = 0.4(I_{MAX})$. The largest ripple current occurs at the highest V_{IN}. To guarantee that the ripple current stays below a specified maximum, the inductor value should be chosen according to the following equation :

$$L = \left[\frac{V_{OUT}}{f \times \Delta I_{L(MAX)}}\right]\left[1 - \frac{V_{OUT}}{V_{IN(MAX)}}\right]$$

The transition from low current operation begins when the peak inductor current falls below the minimum peak current. Lower inductor values result in higher ripple current which causes this to occur at lower load currents. This causes a dip in efficiency in the upper range of low current operation.

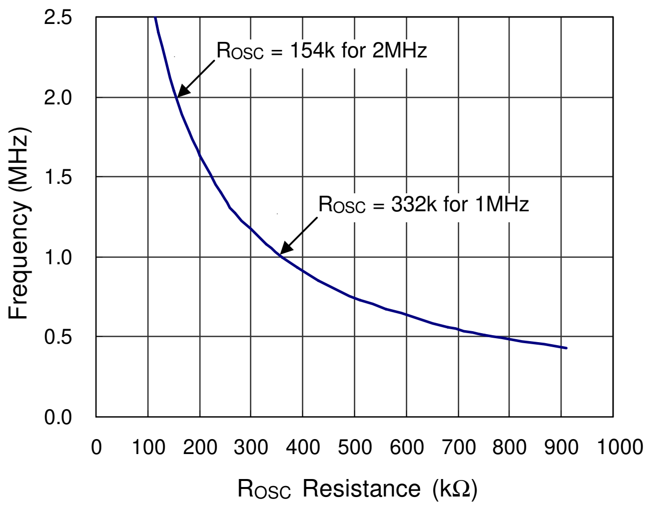


Figure 1. Switching Frequency vs. ROSC Resistance

Inductor Core Selection

Once the value for L is known, the type of inductor must be selected. High efficiency converters generally cannot afford the core loss found in low cost powdered iron cores, forcing the use of more expensive ferrite or mollypermalloy cores. Actual core loss is independent of core size for a fixed inductor value but it is very dependent on the inductance selected. As the inductance increases, core losses decrease. Unfortunately, increased inductance requires more turns of wire and therefore copper losses will increase.

Ferrite designs have very low core losses and are preferred at high switching frequencies, so design goals can concentrate on copper loss and preventing saturation. Ferrite core material saturates "hard", which means that inductance collapses abruptly when the peak design current is exceeded.

This result in an abrupt increase in inductor ripple current and consequent output voltage ripple.

Do not allow the core to saturate!

Different core materials and shapes will change the size/current and price/current relationship of an inductor. Toroid or shielded pot cores in ferrite or permalloy materials are small and don't radiate energy but generally cost more than powdered iron core inductors with similar characteristics. The choice of which style inductor to use mainly depends on the price vs. size requirements and any radiated field/EMI requirements.

C_{IN} and C_{OUT} Selection

The input capacitance, C_{IN}, is needed to filter the trapezoidal current at the source of the top MOSFET. To prevent large ripple voltage, a low ESR input capacitor sized for the maximum RMS current should be used. RMS current is given by :

$$I_{RMS} = I_{OUT(MAX)} \frac{V_{OUT}}{V_{IN}} \sqrt{\frac{V_{IN}}{V_{OUT}} - 1}$$

This formula has a maximum at $V_{IN} = 2V_{OUT}$, where $I_{RMS} = I_{OUT}/2$. This simple worst-case condition is commonly used for design because even significant deviations do not offer much relief. Note that ripple current ratings from capacitor manufacturers are often based on only 2000 hours of life which makes it advisable to further derate the capacitor, or choose a capacitor rated at a higher temperature than required.

Several capacitors may also be paralleled to meet size or height requirements in the design.

The selection of C_{OUT} is determined by the effective series resistance (ESR) that is required to minimize voltage ripple and load step transients, as well as the amount of bulk capacitance that is necessary to ensure that the control loop is stable. Loop stability can be checked by viewing the load transient response as described in a later section. The output ripple, ΔV_{OUT}, is determined by :

$$\Delta V_{OUT} \le \Delta I_L \left[ESR + \frac{1}{8fC_{OUT}} \right]$$

The output ripple is highest at maximum input voltage since ΔI_L increases with input voltage. Multiple capacitors placed in parallel may be needed to meet the ESR and RMS current handling requirements. Dry tantalum, special polymer, aluminum electrolytic and ceramic capacitors are all available in surface mount packages. Special polymer capacitors offer very low ESR but have lower capacitance density than other types. Tantalum capacitors have the highest capacitance density but it is important to only use types that have been surge tested for use in switching power supplies. Aluminum electrolytic capacitors have significantly higher ESR but can be used in cost-sensitive applications provided that consideration is given to ripple current ratings and long term reliability. Ceramic capacitors have excellent low ESR characteristics but can have a high voltage coefficient and audible piezoelectric effects. The high Q of ceramic capacitors with trace inductance can also lead to significant ringing.

Using Ceramic Input and Output Capacitors

Higher values, lower cost ceramic capacitors are now becoming available in smaller case sizes. Their high ripple current, high voltage rating and low ESR make them ideal for switching regulator applications. However, care must be taken when these capacitors are used at the input and output. When a ceramic capacitor is used at the input and the power is supplied by a wall adapter through long wires, a load step at the output can induce ringing at the input, V_{IN}. At best, this ringing can couple to the output and be mistaken as loop instability. At worst, a sudden inrush of current through the long wires can potentially cause a voltage spike at V_{IN} large enough to damage the part.

Output Voltage Programming

The output voltage is set by an external resistive divider according to the following equation :

$$V_{OUT} = V_{REF} \times \left(1 + \frac{R1}{R2}\right)$$

where V_{REF} equals to 0.8V typical.

The resistive divider allows the FB pin to sense a fraction of the output voltage as shown in Figure 2.

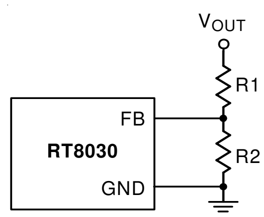
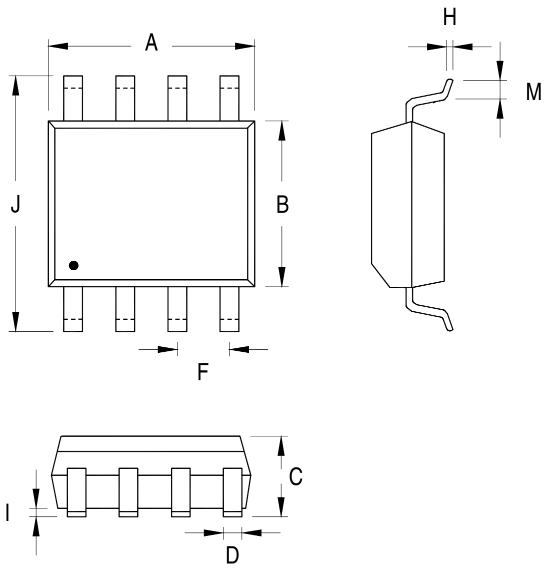


Figure 2. Setting the Output Voltage

Outline Dimension



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	4.801	5.004	0.189	0.197
B	3.810	3.988	0.150	0.157
C	1.346	1.753	0.053	0.069
D	0.330	0.508	0.013	0.020
F	1.194	1.346	0.047	0.053
H	0.170	0.254	0.007	0.010
I	0.050	0.254	0.002	0.010
J	5.791	6.200	0.228	0.244
M	0.400	1.270	0.016	0.050

8-Lead SOP Plastic Package

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