1.5MHz, 1A, High Efficiency PWM Step-Down DC/DC Converter

General Description

The RT8080 is a high efficiency Pulse-Width-Modulated (PWM) step-down DC/DC converter. Capable of delivering 1A output current over a wide input voltage range from 2.8V to 5.5V, the RT8080 is ideally suited for portable electronic devices that are powered from 1-cell Li-ion battery or from other power sources such as cellular phones, PDAs and hand-held devices.

Two operating modes are available including : PWM/Low-Dropout auto switch and shutdown modes. The Internal synchronous rectifier with low $R_{DS(ON)}$ dramatically reduces conduction loss at PWM mode. No external Schottky diode is required in practical application.

The RT8080 enters Low Dropout mode when normal PWM cannot provide regulated output voltage by continuously turning on the upper P-MOSFET. When EN pin is pulled low, the RT8080 will enter shutdown mode and consume less than 0.1μA.

The switching ripple is easily smoothed-out by small package filtering elements due to a fixed operating frequency of 1.5MHz. This along with small WDFN-6L 2x2 package provides small PCB area application. Other features include soft start, lower internal reference voltage with 2% accuracy, over temperature protection, and over current protection.

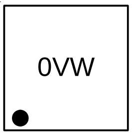
Features

- **2.8V to 5.5V Input Range**
- **Adjustable Output From 0.6V to V_{IN}**
- **1A Output Current**
- **95% Efficiency**
- **No Schottky Diode Required**
- **1.5MHz Fixed-Frequency PWM Operation**
- **Small 6-Lead WDFN Package**
- **RoHS Compliant and Halogen Free**

Applications

- Mobile Phones
- Personal Information Appliances
- Wireless and DSL Modems
- MP3 Players
- Portable Instruments

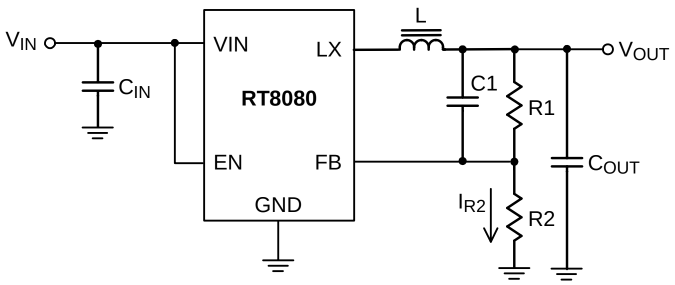
Marking Information



0V : Product Code

W : Date Code

Simplified Application Circuit



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Ordering Information

RT8080□□
Package Type
QW : WDFN-6L 2x2 (W-Type)
Lead Plating System
G : Green (Halogen Free and Pb Free)

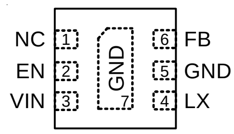
Note :

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.

Pin Configurations

(TOP VIEW)

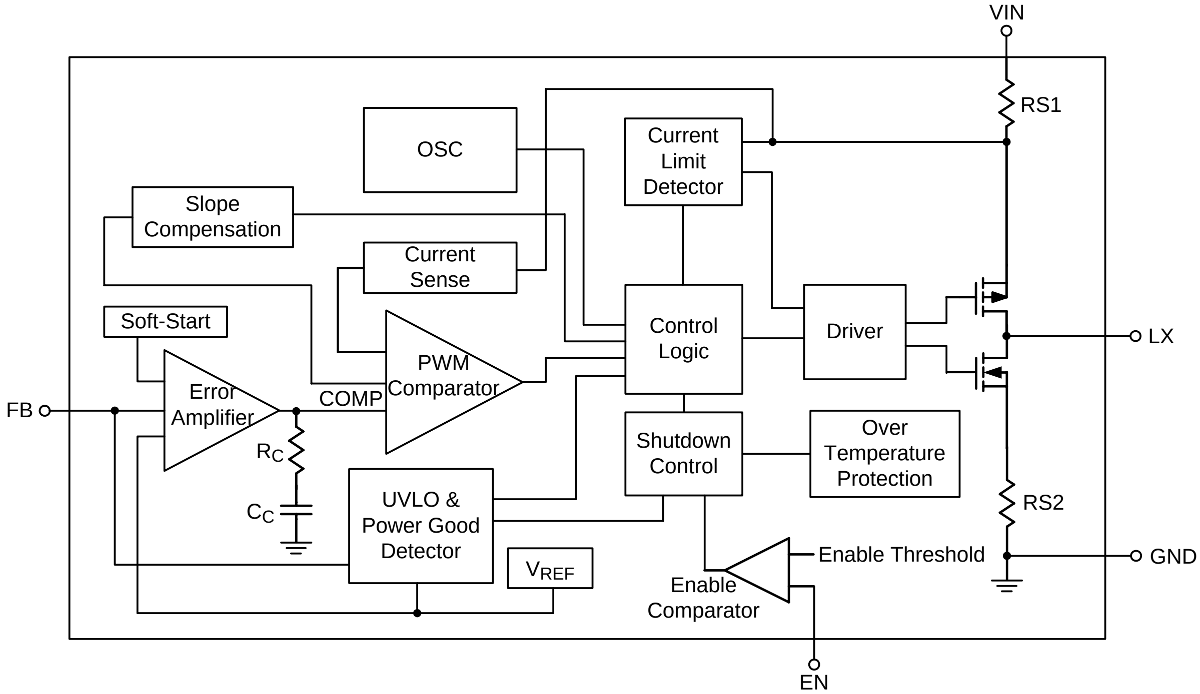


WDFN-6L 2x2

Functional Pin Description

Pin No.	Pin Name	Pin Function
1	NC	No Internal Connection.
2	EN	Chip Enable (Active High).
3	VIN	Power Input.
4	LX	Switch Node.
5, 7 (Exposed Pad)	GND	Ground. The exposed pad must be soldered to a large PCB and connected to GND for maximum power dissipation.
6	FB	Feedback Voltage Input.

Function Block Diagram



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Operation

The RT8080 is a synchronous step-down DC/DC converter with two integrated power MOSFETs and operates at 1.5MHz fixed frequency. It can deliver up to 1A output current from a 2.8V to 5.5V input supply. The RT8080's current mode architecture allows the transient response to be optimized over a wide input voltage and load range. Cycle-by-cycle current limit provides protection against shorted output and soft-start eliminates input current surge during start-up. The RT8080 is available in WDFN-6L 2x2 (Exposed Pad) packages.

The peak current of high side MOSFET is measured by internal sensing resistor. The Current Signal combines current sense with slope compensation and compares with COMP voltage by the PWM comparator. The error amplifier adjusts COMP voltage by comparing the feedback signal (V_{FB}) from the output voltage with the internal 0.6V reference. When the load current increases, it causes a drop in the feedback voltage relative to the reference, and the COMP voltage will rise to allow higher inductor current to match the load current.

OSC

The internal oscillator typically runs at 1.5 MHz switching frequency.

Over Temperature Protection (OTP)

The RT8080 implement an internal over temperature protection. When junction temperature is higher than 150°C, it will stop switching. Once the junction temperature decreases below 130°C, the RT8080 will automatically resume switching.

Enable Comparator

When EN pin input voltage is higher/lower than EN threshold voltage, the converter is enabled/disabled. The EN pin can be connected to VIN directly for automatic startup.

Soft-Start (SS)

An internal current source charges an internal capacitor to build the soft-start ramp-voltage (V_{SS}). The V_F voltage will track the internal ramp voltage during the soft-start interval.

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Absolute Maximum Ratings (Note 1)

- Supply Input Voltage, VIN ---------- −0.3V to 6.5V
- EN, FB to GND ---------- −0.3V to V_{IN}
- LX to GND ---------- −0.3V to (V_{IN} + 0.3V)
  <20ns ---------- −4.5V to 7.5V
- Power Dissipation, P_D @ T_A = 25°C
  WDFN-6L 2x2 ---------- 0.833W
- Package Thermal Resistance (Note 2)
  WDFN-6L 2x2, θ_{JA} ---------- 120°C/W
  WDFN-6L 2x2, θ_{JC} ---------- 8.2°C/W
- Lead Temperature (Soldering, 10 sec.) ---------- 260°C
- Storage Temperature Range ---------- −65°C to 150°C
- Junction Temperature ---------- 150°C
- ESD Susceptibility (Note 3)
  HBM (Human Body Model) ---------- 2kV

Recommended Operating Conditions (Note 4)

- Supply Input Voltage, VIN ---------- 2.8V to 5.5V
- Junction Temperature Range ---------- −40°C to 125°C
- Ambient Temperature Range ---------- −40°C to 85°C

Electrical Characteristics

(V_{IN} = 3.6V, T_A = 25°C, unless otherwise specified)

Parameter		Symbol	Test Conditions	Min	Typ	Max	Unit
Quiescent Current		I_Q	I_{OUT} = 0mA, V_{FB} = V_{REF} + 5%	--	78	--	μA
Shutdown Current		I_{SHDN}	EN = GND	--	0.1	1	μA
Reference Voltage		V_{REF}		0.588	0.6	0.612	V
Adjustable Output Range		V_{OUT}	(Note 5)	V_{REF}	--	V_{IN} − 0.2V	V
FB Input Current		I_{FB}	V_{FB} = V_{IN}	−50	--	50	nA
P-MOSFET On Resistance		$R_{DS(ON)\_P}$	I_{OUT} = 200mA	--	0.25	--	Ω
N-MOSFET On Resistance		$R_{DS(ON)\_N}$	I_{OUT} = 200mA	--	0.25	--	Ω
P-Channel Current Limit		I_{LIM_P}	V_{IN} = 2.8V to 5.5V	1.3	1.5	--	A
EN Input Voltage	High-Level	V_{EN_H}	V_{IN} = 2.8V to 5.5V	1.5	--	--	V
	Low-Level	V_{EN_L}	V_{IN} = 2.8V to 5.5V	--	--	0.4	
Under Voltage Lockout Threshold		UVLO		--	2.3	--	V
UVLO Hysteresis				--	0.2	--	V
Oscillator Frequency		f_{OSC}	V_{IN} = 3.6V, I_{OUT} = 100mA	1.2	1.5	1.8	MHz
Thermal Shutdown Temperature		T_{SD}		--	150	--	°C
Maximum Duty Cycle				100	--	--	%

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Note 1. Stresses beyond those listed "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and 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 may affect device reliability.

Note 2. θ_{JA} is measured at T_A = 25°C on a high effective thermal conductivity four-layer test board per JEDEC 51-7. θ_{JC} is measured at the exposed pad of the package.

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

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

Note 5. Guarantee by design.

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RICHTEK

Typical Application Circuit

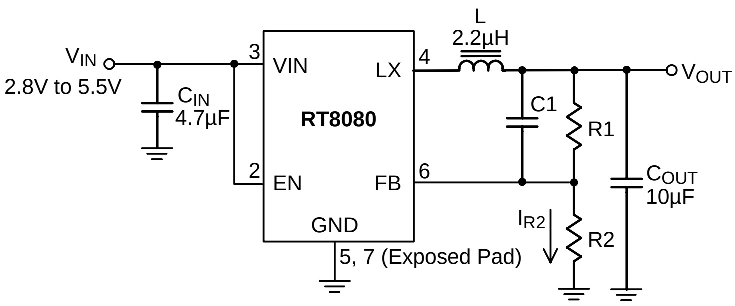

Table 1. Recommended Component Selection

V_{OUT} (V)	C_{IN} (µF)	C_{OUT} (µF)	C1 (pF)	L (µH)	R1 (kΩ)	R2 (kΩ)
1.2	4.7	10	10	2.2	62	62
3.3	4.7	10	10	2.2	280	62

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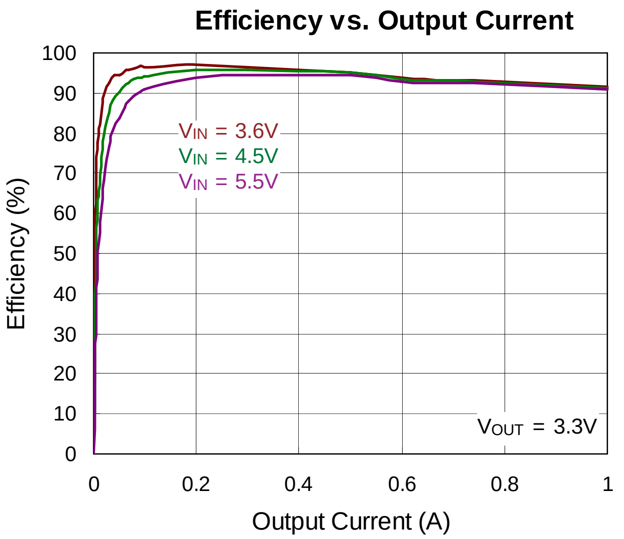
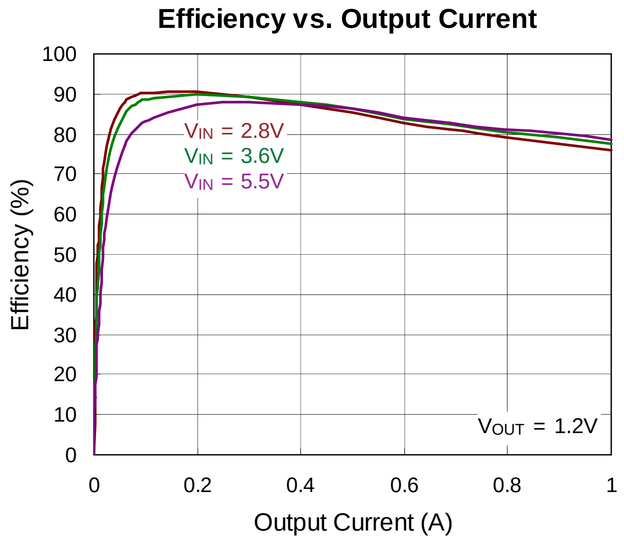
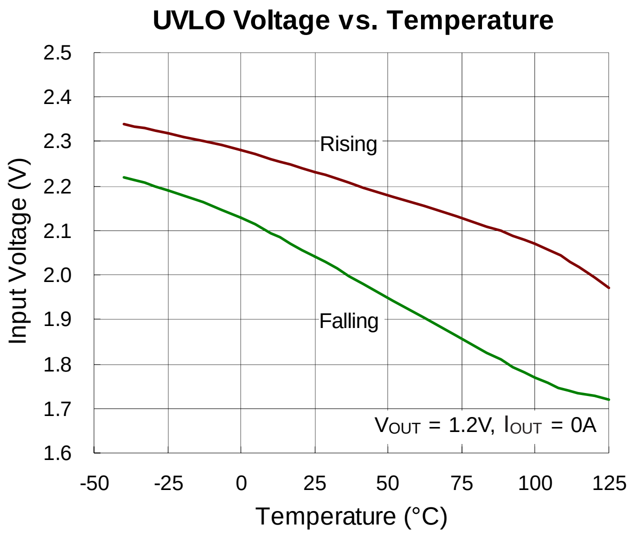
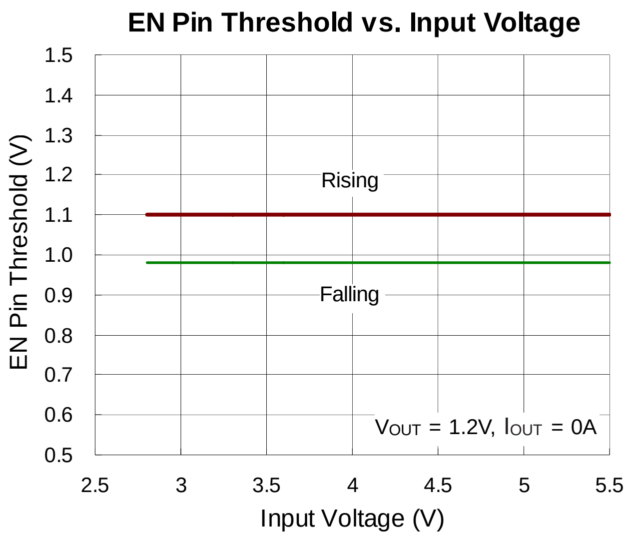
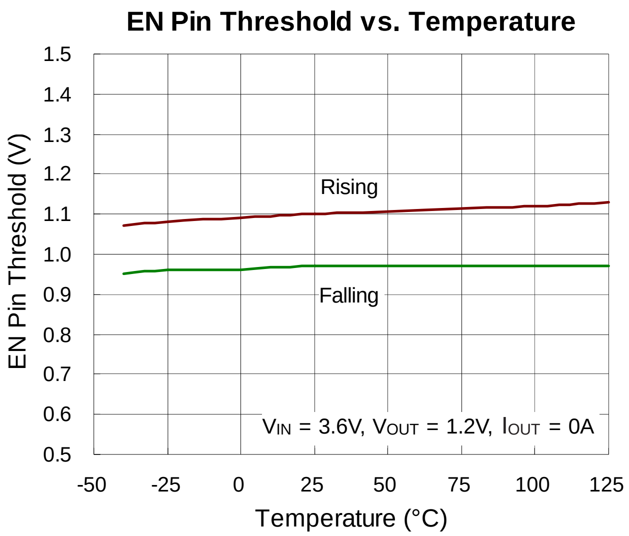
Typical Operating Characteristics

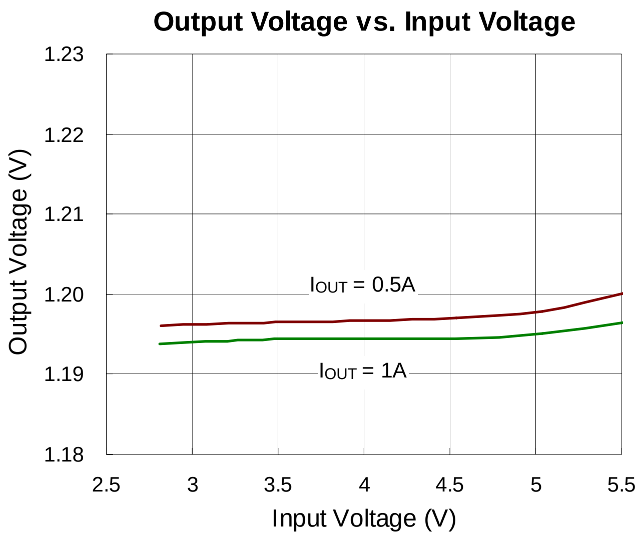












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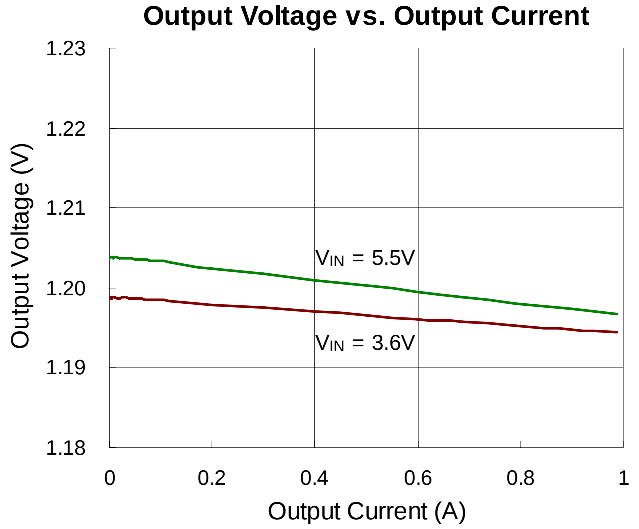

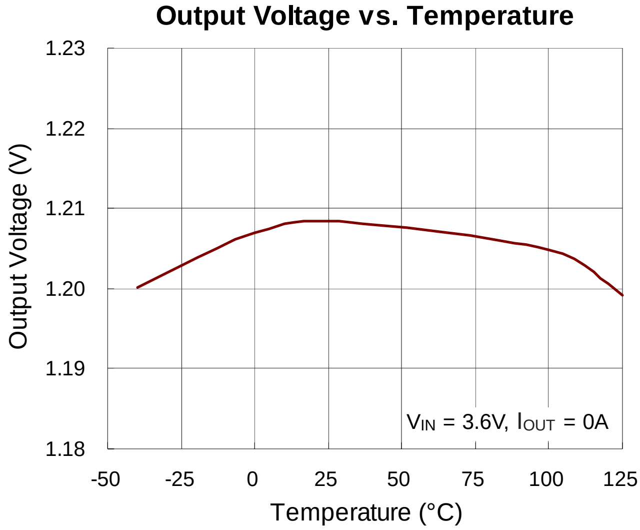

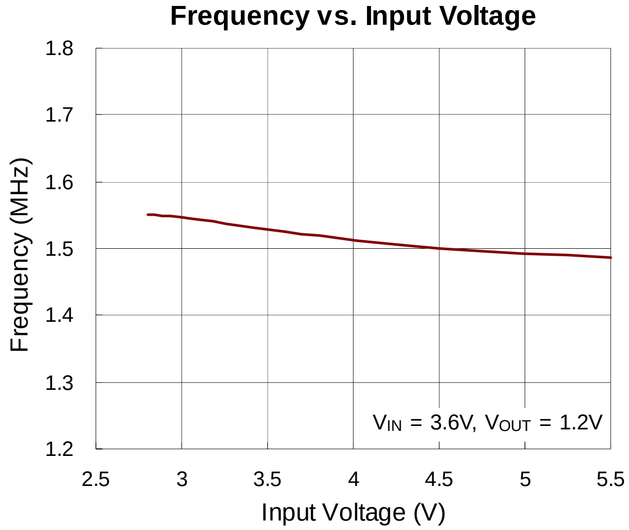

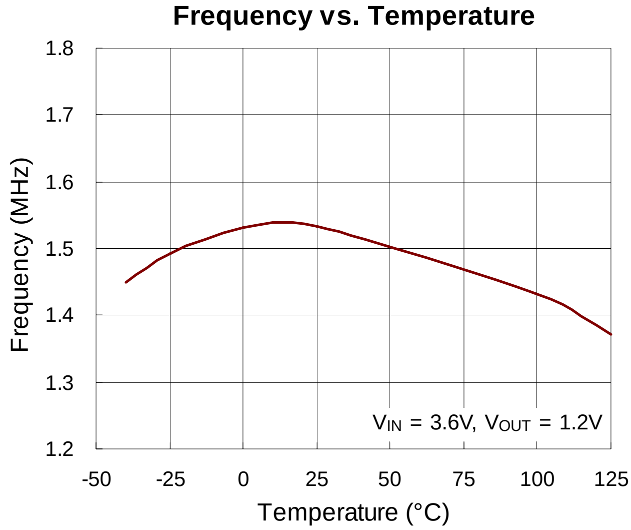

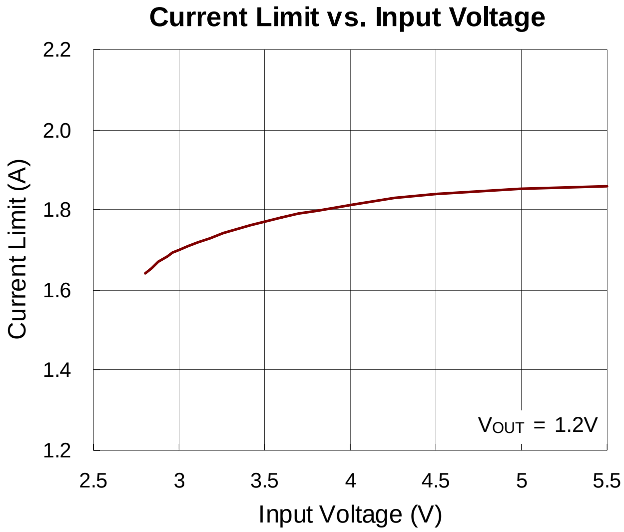

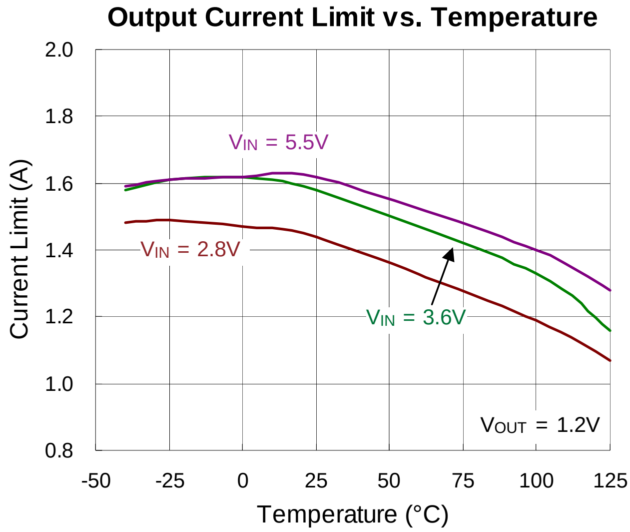

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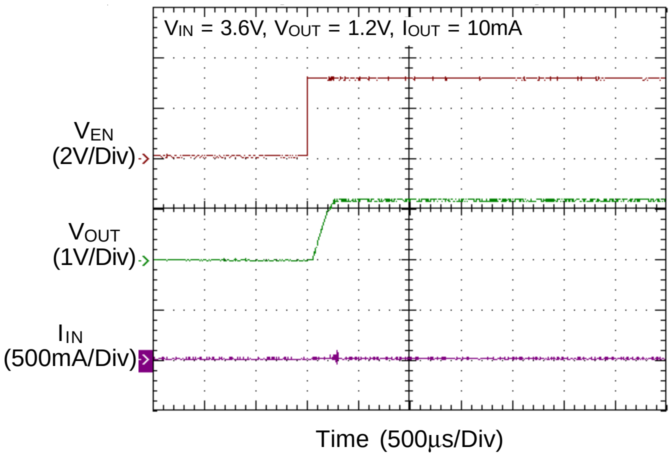
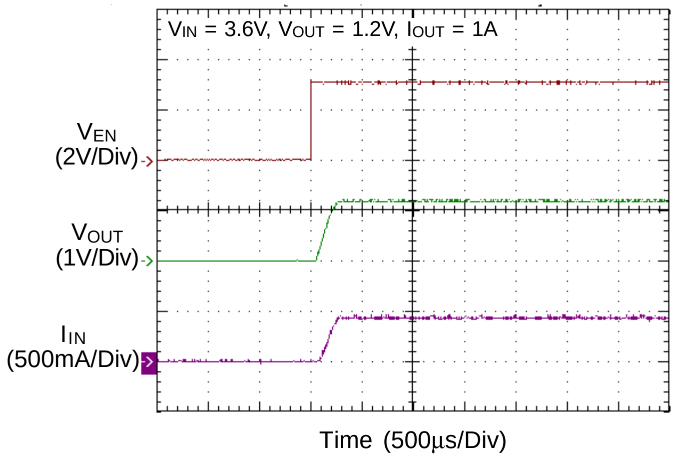
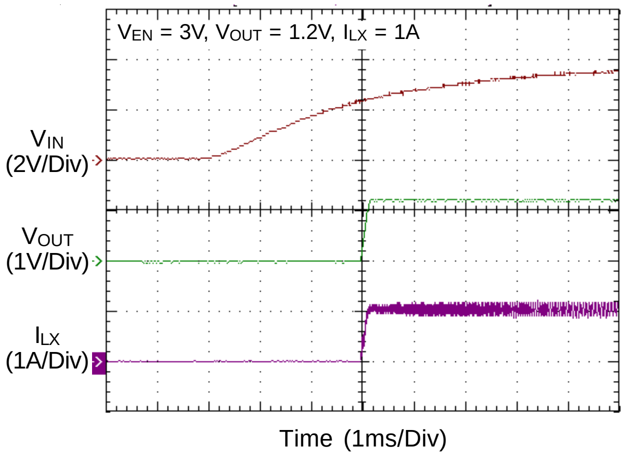
Power On from EN



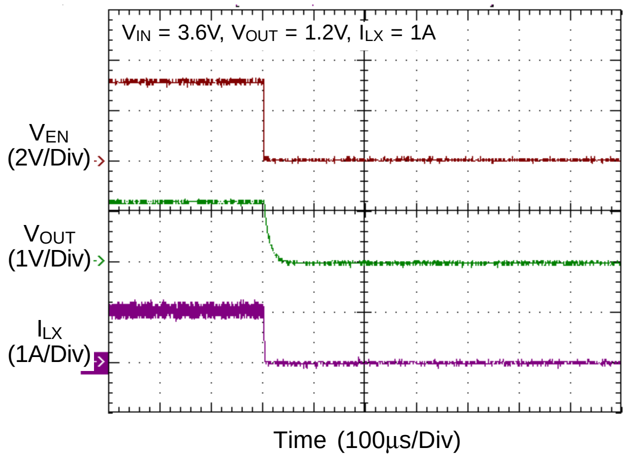
Power On from EN



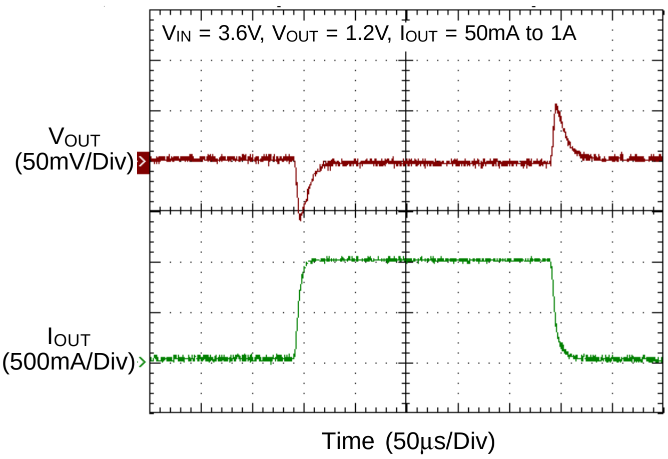
Power On from VIN



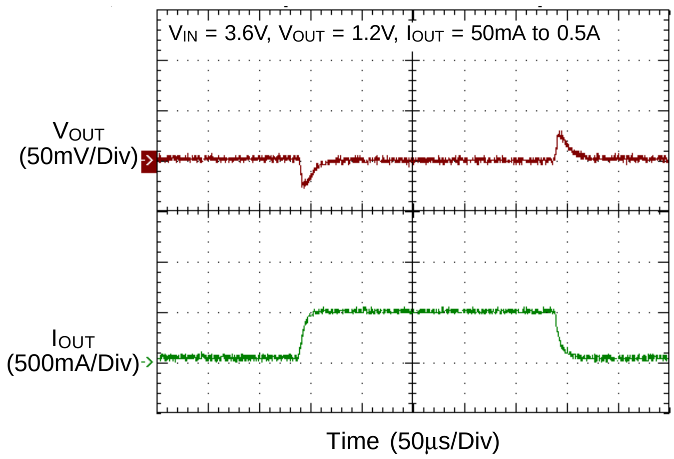
Power Off from EN



Load Transient Response



Load Transient Response



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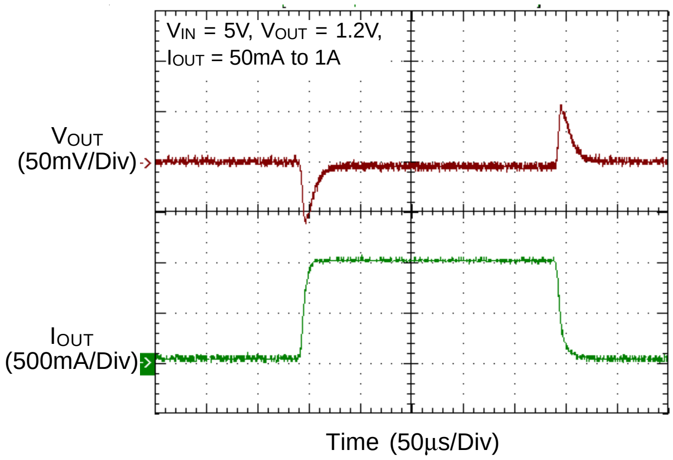
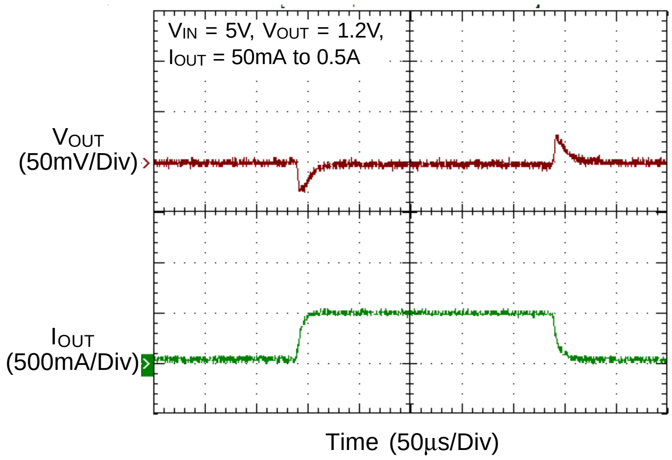
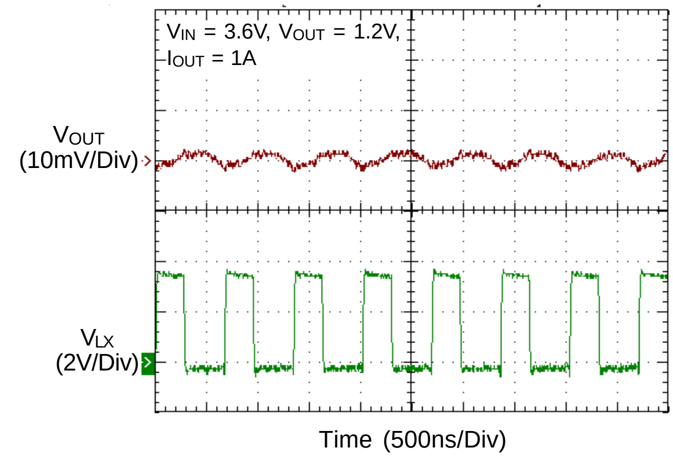
Load Transient Response



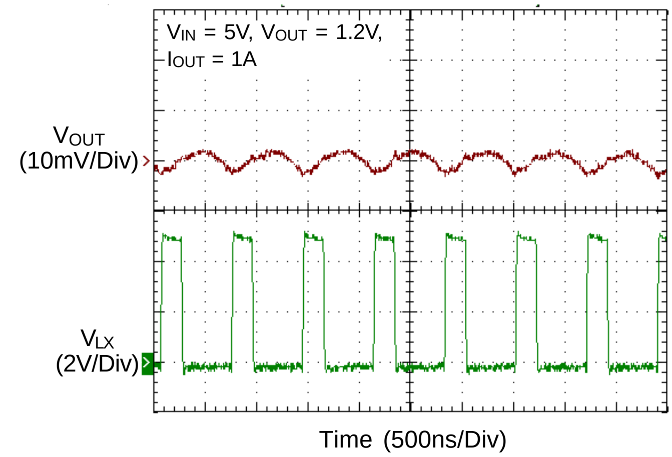
Load Transient Response



Output Ripple Voltage



Output Ripple Voltage



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Applications Information

The basic RT8080 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}.

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.

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

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 $\Delta I_L = 0.4(I_{MAX})$. 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 :

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

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 results 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 :

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

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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 resistive divider allows the FB pin to sense a fraction of the output voltage as shown in Figure 1.

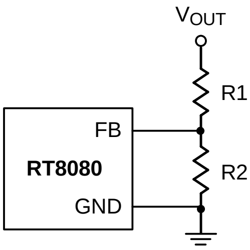

Figure 1. Setting the Output Voltage

For adjustable voltage mode, the output voltage is set by an external resistive divider according to the following equation :

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

where V_{REF} is the internal reference voltage (0.6V typ.)

Thermal Considerations

The maximum power dissipation depends on the thermal resistance of IC package, PCB layout, the rate of surroundings airflow and temperature difference between junction to ambient. The maximum power dissipation can be calculated by following formula :

$P_{D(MAX)} = (T_{J(MAX)} - T_A) / \theta_{JA}$

Where $T_{J(MAX)}$ is the maximum operation junction temperature, T_A is the ambient temperature and the θ_{JA} is the junction to ambient thermal resistance.

For recommended operating condition specifications, the maximum junction temperature is 125°C. The junction to ambient thermal resistance, θ_{JA}, is layout dependent. For WDFN-6L 2x2 packages, the thermal resistance θ_{JA} is 120°C/W on the standard JEDEC 51-7 four layers thermal test board. The maximum power dissipation at T_A = 25°C can be calculated by following formula :

$P_{D(MAX)}$ = (125°C − 25°C) / 120°C/W = 0.833W for WDFN-6L 2x2 packages

The maximum power dissipation depends on the operating ambient temperature for fixed $T_{J(MAX)}$ and thermal resistance, θ_{JA}. The derating curve in Figure 2 of derating curves allows the designer to see the effect of rising ambient temperature on the maximum power allowed.

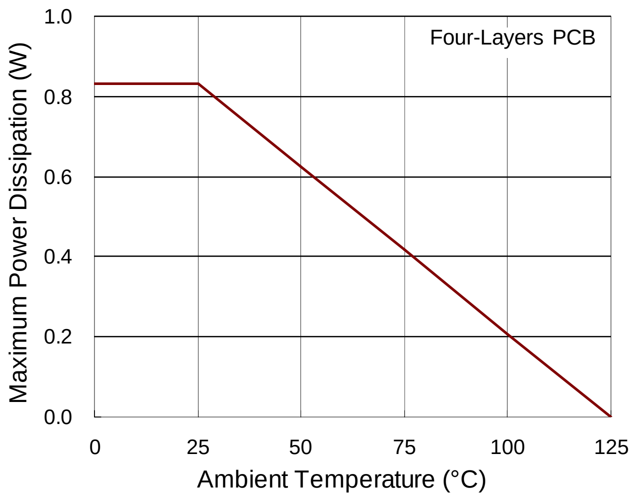

Figure 2. Derating Curve of Maximum Power Dissipation

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Layout Considerations

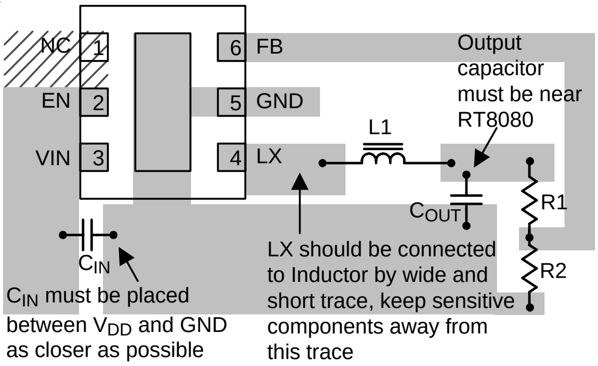

Figure 3. PCB Layout Guide

Layout note :

1. The distance that C_{IN} connects to V_{IN} is as close as possible (Under 2mm).
2. C_{OUT} should be placed near RT8080.

Table 2. Recommended Inductors

Supplier	Inductance (μH)	Current Rating (mA)	DCR (mΩ)	Dimensions (mm)	Series
TAIYO YUDEN	2.2	1480	60	3.00 x 3.00 x 1.50	NR 3015
GOTREND	2.2	1500	58	3.85 x 3.85 x 1.80	GTSD32
Sumida	2.2	1500	75	4.50 x 3.20 x 1.55	CDRH2D14

Table 3. Recommended Capacitors for C_{IN} and C_{OUT}

Supplier	Capacitance (μF)	Package	Part Number
TDK	4.7	603	C1608JB0J475M
MURATA	4.7	603	GRM188R60J475KE19
TAIYO YUDEN	4.7	603	JMK107BJ475RA
TAIYO YUDEN	10	603	JMK107BJ106MA
TDK	10	805	C2012JB0J106M
MURATA	10	805	GRM219R60J106ME19
MURATA	10	805	GRM219R60J106KE19
TAIYO YUDEN	10	805	JMK212BJ106RD

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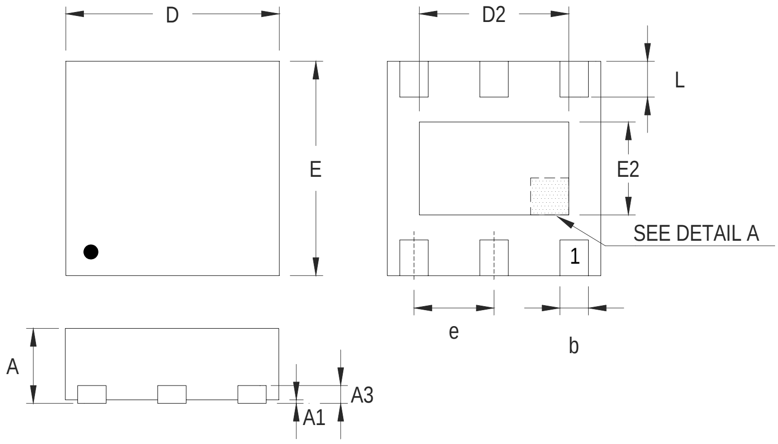
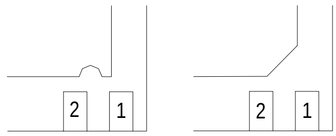
Outline Dimension





DETAIL A

Pin #1 ID and Tie Bar Mark Options

Note : The configuration of the Pin #1 identifier is optional, but must be located within the zone indicated.

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A3	0.175	0.250	0.007	0.010
b	0.200	0.350	0.008	0.014
D	1.950	2.050	0.077	0.081
D2	1.000	1.450	0.039	0.057
E	1.950	2.050	0.077	0.081
E2	0.500	0.850	0.020	0.033
e	0.650		0.026	
L	0.300	0.400	0.012	0.016

W-Type 6L DFN 2x2 Package

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