

## GENERAL DESCRIPTION

The XRP6124 is a non synchronous step down (buck) controller for up to 5Amps point of loads. A wide 3V to 30V input voltage range allows for single supply operations from industry standard 3.3V, 5V, 12V and 24V power rails.

With a proprietary Constant On-Time (COT) control scheme, the XRP6124 provides extremely fast line and load transient response while the operating frequency remains nearly constant. It requires no loop compensation hence simplifying circuit implementation and reducing overall component count. The XRP6124 also implements an emulated ESR circuitry allowing usage of ceramic output capacitors and insuring stable operations without the use of extra external components.

Built-in soft start prevents high inrush currents while under voltage lock-out and output short protections insure safe operations under abnormal operating conditions.

The XRP6124 is available in a RoHS compliant, green/halogen free space-saving 5-pin SOT23 package.

## APPLICATIONS

- **Point of Load Conversions**
- **Audio-Video Equipments**
- **Industrial and Medical Equipments**
- **Distributed Power Architecture**

## FEATURES

- **5A Point-of-Load Capable**
  - Down to 1.2V Output Voltage Conversion
- **Wide Input Voltage Range**
  - 3V to 18V: XRP6124
  - 4.5V to 30V: XRP6124HV
- **Constant On-Time Operations**
  - Constant Frequency Operations
  - No External Compensation
  - Supports Ceramic Output Capacitors
- **Built-in 2ms Soft Start**
- **Short Circuit Protection**
- **<1 $\mu$ A shutdown current**
- **RoHS Compliant, Green/Halogen Free 5-pin SOT23 Package**

## TYPICAL APPLICATION DIAGRAM

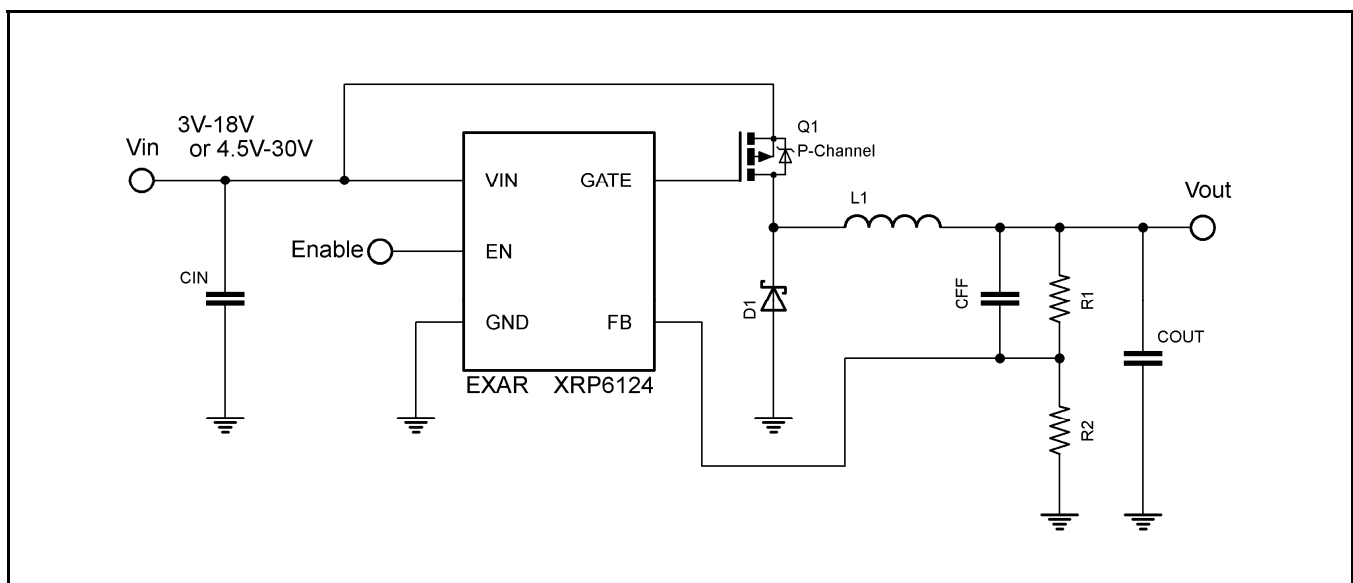


Figure 1: XRP6124 Application Diagram



**ABSOLUTE MAXIMUM RATINGS**

These are stress ratings only and functional operation of the device at these ratings or any other above those indicated in the operation sections of the specifications below is not implied. Exposure to absolute maximum rating conditions for extended periods of time may affect reliability.

V<sub>IN</sub> (XRP6124)..... -0.3V to 20V  
 V<sub>IN</sub> (XRP6124HV)..... -0.3V to 32V  
 GATE ..... VIN-GATE<8V  
 FB, EN ..... -0.3V to 5.5V  
 Storage Temperature ..... -65°C to 150°C  
 Power Dissipation ..... Internally Limited  
 Lead Temperature (Soldering, 10 sec) ..... 300°C  
 ESD Rating (HBM - Human Body Model)..... 2kV

**OPERATING RATINGS**

Input Voltage Range V<sub>IN</sub> (XRP6124).....3.0V to 18V  
 Input Voltage Range V<sub>IN</sub> (XRP6124HV).....4.5V to 30V  
 Junction Temperature Range .....-40°C to 125°C  
 Thermal Resistance  $\theta_{JA}$  .....191°C/W

**ELECTRICAL SPECIFICATIONS**

Specifications are for an Operating Junction Temperature of T<sub>J</sub> = 25°C only; limits applying over the full Operating Junction Temperature range are denoted by a “•”. Minimum and Maximum limits are guaranteed through test, design, or statistical correlation. Typical values represent the most likely parametric norm at T<sub>J</sub> = 25°C, and are provided for reference purposes only. Unless otherwise indicated, V<sub>IN</sub> = 3.0V to 18V, T<sub>J</sub> = -40°C to 125°C.

Parameter	Min.	Typ.	Max.	Units	Conditions
UVLO Turn-On Threshold	2.5	2.8	3.0	V	• XRP6124
UVLO Turn-On Threshold	3.8	4.2	4.5	V	• XRP6124HV
UVLO Hysteresis		0.1		V	
Operating Input Voltage Range	3.0		18	V	• XRP6124
	4.5		30	V	• XRP6124HV
Shutdown VIN Current		1.5	3	µA	EN=0V, V <sub>IN</sub> =12V
Operating VIN Current		0.5	1	mA	VFB=1.2V and after fault
Reference Voltage	0.792	0.8	0.808	V	
	0.784	0.8	0.816	V	•
VSC_TH, Feedback pin Short Circuit Latch Threshold	0.50	0.55	0.65	V	•
T <sub>ON</sub> , Switch On-Time	0.4	0.5	0.6	µs	• V <sub>IN</sub> =12V, XRP6124
T <sub>ON</sub> , Switch On-Time	0.4	0.5	0.6	µs	• V <sub>IN</sub> =24V, XRP6124HV
T <sub>OFF_MIN</sub> , Minimum Off-Time		250	350	ns	• V <sub>IN</sub> =12V
Soft Start Time		2		ms	
EN Turn-On Threshold	2			V	
EN Turn-Off Threshold			1	V	
EN Bias Current		0.01	0.1	µA	
Gate Driver Pull-Down Resistance		6	9	Ω	
Gate Driver Pull-up Resistance		5	8	Ω	
t <sub>r</sub> , gate rise time		45		ns	C <sub>GATE</sub> =1nF
t <sub>f</sub> , gate fall time		35		ns	C <sub>GATE</sub> =1nF
VIN - GATE voltage difference	5.5	6.4	8	V	• VIN=12V
VIN - GATE voltage difference	2.6			V	• VIN=3.0V

**BLOCK DIAGRAM**

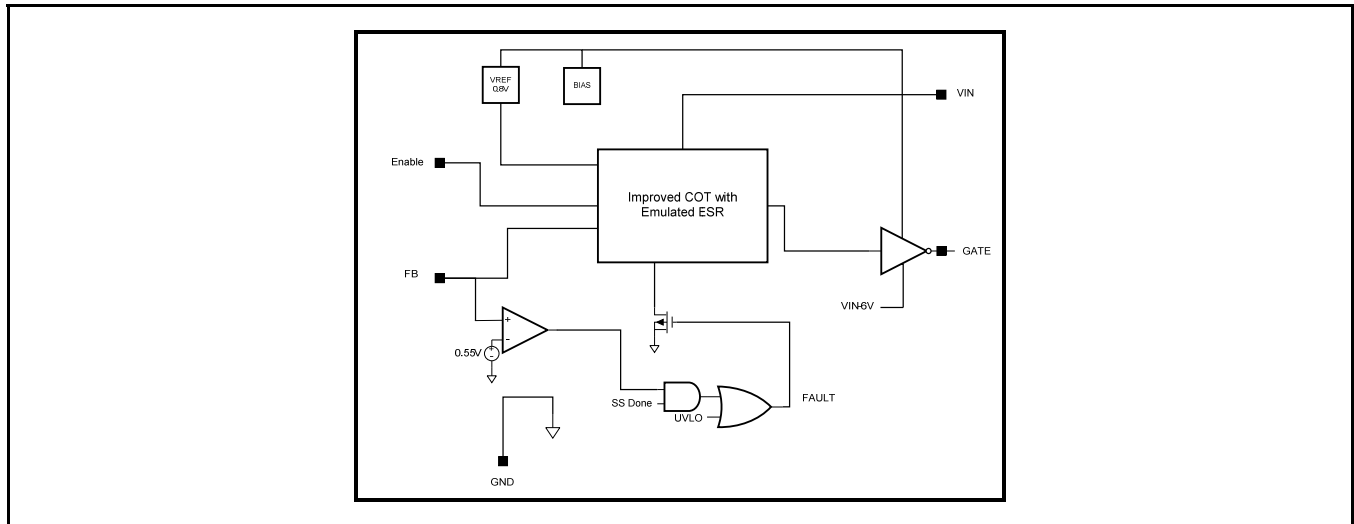


Figure 2: XRP6124 Block Diagram

**PIN ASSIGNMENT**

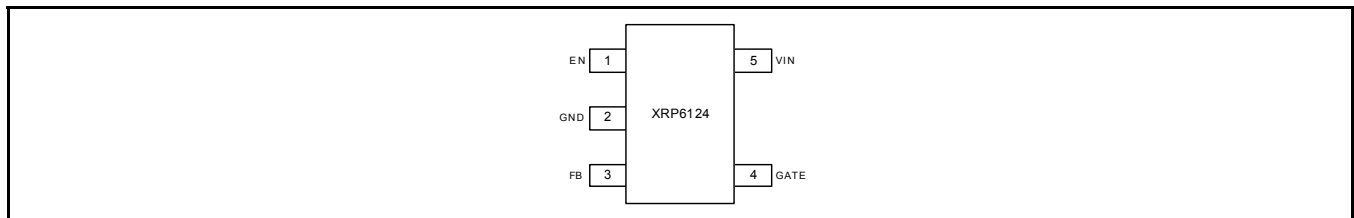


Figure 3: XRP6124 Pin Assignment

**PIN DESCRIPTION**

Name	Pin Number	Description
EN	1	Enable Pin. Actively pull high to enable the part.
GND	2	Ground
FB	3	Feedback pin
GATE	4	Gate Pin. Connect to gate of PFET. This pin pulls the gate of the PFET approximately 6V below Vin in order to turn on the FET. For 6V>VIN>3V the gate pulls to within 0.4V of ground. Therefore a PFET with a gate rating of 2.6V or lower should be used.
VIN	5	Input Voltage

**ORDERING INFORMATION**

Part Number	Temperature Range	Marking	Package	Packing Quantity	Note 1	Note 2
XRP6124ES0.5-F	-40°C ≤ T <sub>J</sub> ≤ 125°C		5-pin SOT23	Bulk	Halogen Free	0.5µs/18V max
XRP6124ESTR0.5-F	-40°C ≤ T <sub>J</sub> ≤ 125°C		5-pin SOT23	2.5K/Tape & Reel	Halogen Free	0.5µs/18V max
XRP6124HVES0.5-F	-40°C ≤ T <sub>J</sub> ≤ 125°C		5-pin SOT23	Bulk	Halogen Free	0.5µs/30V max
XRP6124HVESTRO.5-F	-40°C ≤ T <sub>J</sub> ≤ 125°C		5-pin SOT23	2.5K/Tape & Reel	Halogen Free	0.5µs/30V max
XRP6124EVB	XRP6124 Evaluation Board					

“YY” = Year – “WW” = Work Week – “X” = Lot Number

**TYPICAL PERFORMANCE CHARACTERISTICS**

All data taken at  $T_J = T_A = 25^\circ\text{C}$ , unless otherwise specified – Curves are based on Schematic and BOM from Application Information section of this datasheet. Refer to figure 20 for XRP6124 and to figure 21 for XRP6124HV.

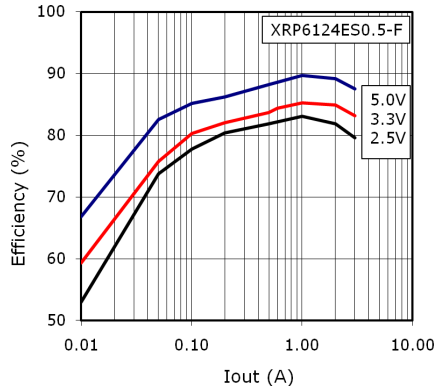


Fig. 4: Efficiency versus  $I_{OUT}$ ,  $V_{IN}=12\text{V}$

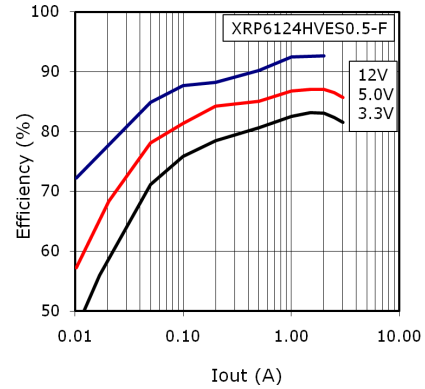


Fig. 5: Efficiency versus  $I_{OUT}$ ,  $V_{IN}=24\text{V}$

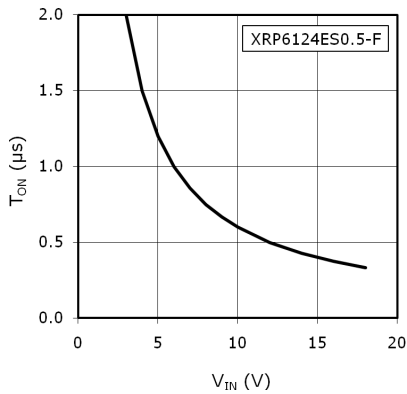


Fig. 6:  $T_{ON}$  versus  $V_{IN}$

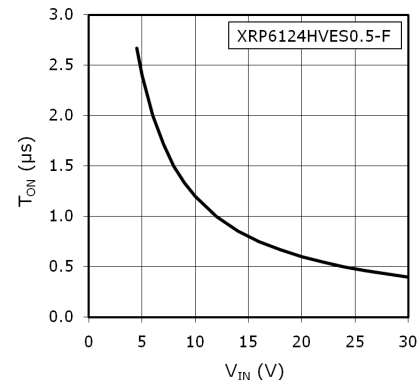


Fig. 7:  $T_{ON}$  versus  $V_{IN}$

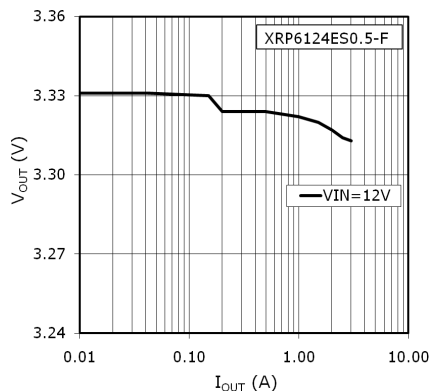


Fig. 8: Load Regulation

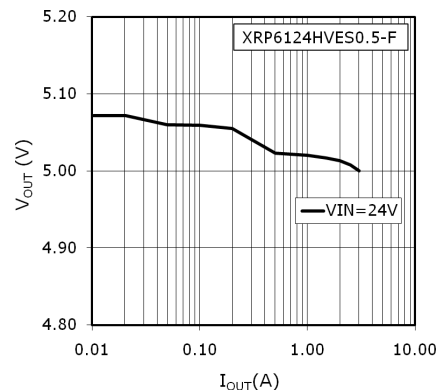


Fig. 9: Load Regulation

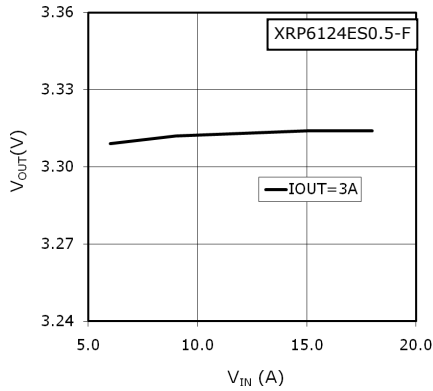


Fig. 10: Line Regulation

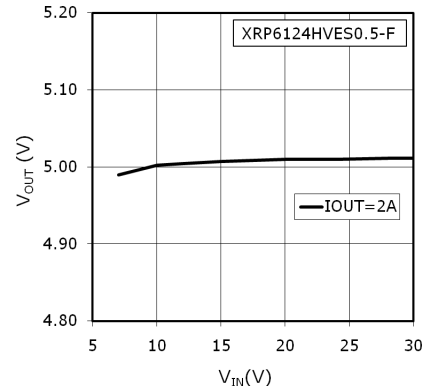


Fig. 11: Line Regulation

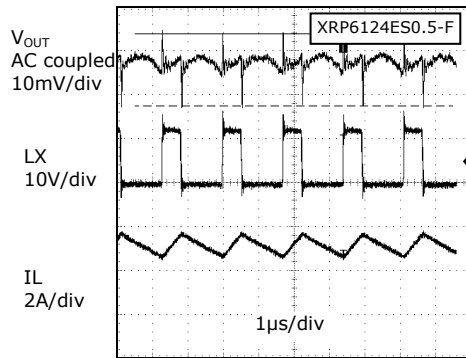


Fig. 12: Steady state,  $V_{IN}=12V$ ,  $V_{OUT}=3.3V$ ,  $I_{OUT}=3A$

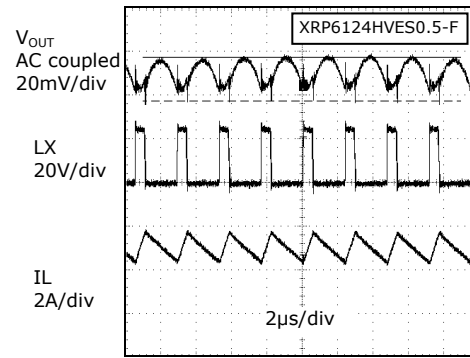


Fig. 13: Steady state,  $V_{IN}=24V$ ,  $V_{OUT}=5.0V$ ,  $I_{OUT}=3A$

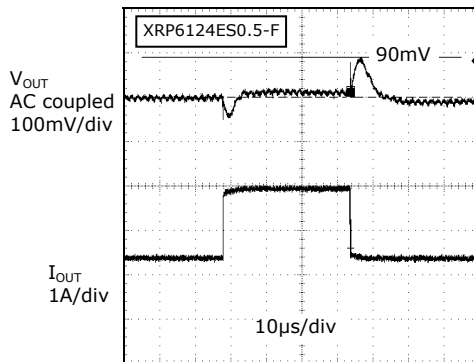


Fig. 14: Load step transient response, 1.4A-3A-1.4A

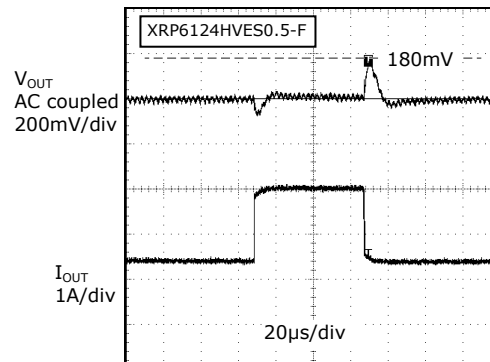


Fig. 15: Load step transient response, 1.4A-3A-1.4A

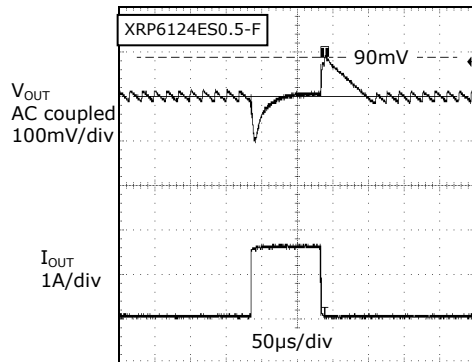


Fig. 16: Load step transient response corresponding to a CCM-DCM transition, 0.05A-1.6A-0.05A

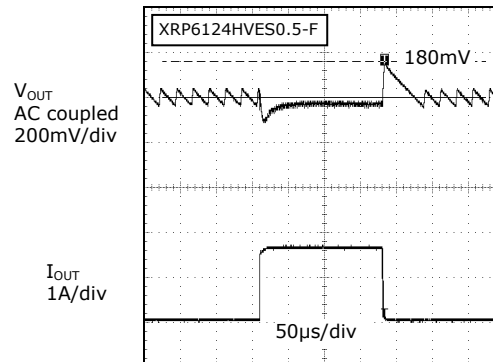


Fig. 17: Load step transient response corresponding to a CCM-DCM transition, 0.05A-1.6A-0.05A

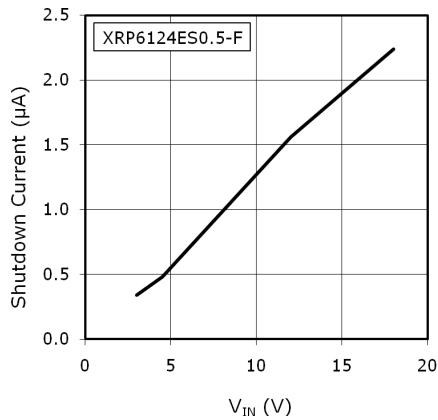


Fig. 18: Shutdown current versus V<sub>IN</sub>, V<sub>EN</sub>=0V

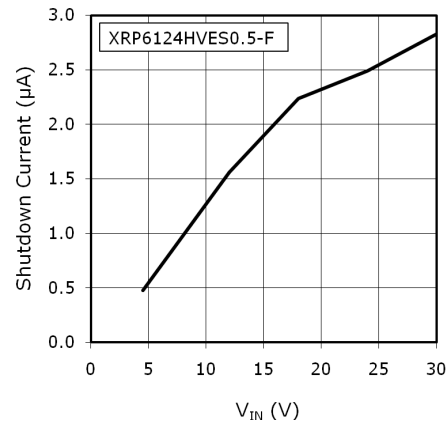


Fig. 19: Shutdown current versus V<sub>IN</sub>, V<sub>EN</sub>=0V

**THEORY OF OPERATION**
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The XRP6124 utilizes a proprietary Constant On-Time (COT) control with emulated ESR. The on-time is internally set and automatically adjusts during operation, inversely with the voltage  $V_{IN}$ , in order to maintain a constant frequency. Therefore the switching frequency is independent of the inductor and capacitor size, unlike hysteretic controllers. The emulated ESR ramp allows the use of ceramic capacitors for output filtering.

At the beginning of each cycle, the XRP6124 turns on the P-Channel FET for a fixed duration. The on-time is internally set and adjusted by  $V_{IN}$ . At the end of the on-time the FET is turned off, for a predetermined minimum off time  $T_{OFF-MIN}$  (nominally 250ns). After the  $T_{OFF-MIN}$  has expired the voltage at feedback pin FB is compared to a voltage ramp at the feedback comparators positive input. Once  $V_{FB}$  drops below the ramp voltage, the FET is turned on and a new cycle starts. This voltage ramp constitutes an emulated ESR and makes possible the use of ceramic capacitors, in addition to other capacitors, as output filter for the buck converter.

**VOLTAGE OPTIONS**

The XRP6124 is available in two voltage options as shown in table 1. The low-voltage and high-voltage options have  $T_{ON}$  of 0.5 $\mu$ s at 12V<sub>IN</sub> and 24V<sub>IN</sub> respectively. Note that  $T_{ON}$  is inversely proportional to  $V_{IN}$ . The constant of proportionality K, for each voltage option is shown in table 1. Variation of  $T_{ON}$  versus  $V_{IN}$  is shown graphically in figures 6 and 7.

Voltage rating (V)	Part Number	$T_{ON}$ ( $\mu$ s)	$K=T_{ON} \times V_{IN}$ ( $\mu$ s.V)
3-18	XRP6124ES0.5-F	0.5 @ 12V <sub>IN</sub>	6
4.5-30	XRP6124HVES0.5-F	0.5 @ 24V <sub>IN</sub>	12

Table 1 : XRP6124 voltage options

For a buck converter the switching frequency  $f_s$  can be expressed in terms of  $V_{IN}$ ,  $V_{OUT}$  and  $T_{ON}$  as follows:

$$f_s = \frac{V_{OUT}}{V_{IN} \times T_{ON}}$$

Since for each voltage option, the product of  $V_{IN}$  and  $T_{ON}$  is the constant K shown in table 1, then switching frequency is determined by  $V_{OUT}$  as shown in table 2.

$V_{OUT}$	Switching frequency $f_s$ (kHz)	
	XRP6124ES0.5-F	XRP6124HVES0.5-F
1.2	200	100
1.5	250	125
1.8	300	150
2.5	417	208
3.3	550	275
5.0	833	417
12	---	1000

 Table 2: Switching frequency  $f_s$  for the XRP6124 voltage options

Where it is advantageous, the high-voltage option may be used for low-voltage applications. For example a 12V<sub>IN</sub> to 5V<sub>OUT</sub> conversion using a low-voltage option will result in switching frequency of 833kHz as shown in table 2. If it is desired to increase the converter efficiency, then switching losses can be reduced in half by using a high-voltage option operating at a switching frequency of 417kHz.

$V_{OUT}$	Maximum Output Current $I_{OUT}$ (A)				
	XRP6124ES0.5-F		XRP6124HVES0.5-F		
	3.3V <sub>IN</sub>	5.0V <sub>IN</sub>	12V <sub>IN</sub>	18V <sub>IN</sub>	24V <sub>IN</sub>
1.2	5	5	4	---	---
1.5	5	5	4	4	---
1.8	5	5	4	4	4
2.5	4	4	4	4	4
3.3	---	4	3	4	4
5.0	---	---	3	3	3
12	---	---	---	2	2

 Table 3: Maximum recommended  $I_{OUT}$ 
**SHORT-CIRCUIT PROTECTION**

The purpose of this feature is to prevent an accidental short-circuit at the output from damaging the converter. The XRP6124 has a short-circuit comparator that constantly monitors the feedback node, after soft-start is

finished. If the feedback voltage drops below 0.55V, equivalent to output voltage dropping below 69% of nominal, the comparator will trip causing the IC to latch off. In order to restart the XRP6124, the input voltage has to be reduced below UVLO threshold and then increased to its normal operating point.

### SOFT-START

To limit in-rush current the XRP6124 has an internal soft-start. The nominal soft-start time is 2ms and commences when  $V_{IN}$  exceeds the UVLO threshold. As explained above, the short-circuit comparator is enabled as soon as soft-start is complete. Therefore if the input voltage has a very slow rising edge such that at the end of soft-start the output voltage has not reached 69% of its final value then the XRP6124 will latch-off.

### ENABLE

By applying a logic-level signal to the enable pin EN the XRP6124 can be turned on and off. Pulling the enable below 1V shuts down the controller and reduces the  $V_{IN}$  leakage current to 1.5 $\mu$ A nominal as seen in figure 18. Enable signal should always be applied after the input voltage or concurrent with it. Otherwise

XRP6124 will latch up. In applications where an independent enable signal is not available, a Zener diode can be used to derive  $V_{EN}$  from  $V_{IN}$ .

### DISCONTINUOUS CONDUCTION MODE, DCM

Because XRP6124 is a non-synchronous controller, when load current  $I_{OUT}$  is reduced to less than half of peak-to-peak inductor current ripple  $\Delta I_L$ , the converter enters DCM mode of operation. The switching frequency  $f_s$  is now  $I_{OUT}$  dependent and no longer governed by the relationship shown in table 2. As  $I_{OUT}$  is decreased so does  $f_s$  until a minimum switching frequency, typically in the range of few hundred Hertz, is reached at no load. This contributes to good converter efficiency at light load as seen in figures 4 and 5. The reduced  $f_s$  corresponding to light load, however, increases the output voltage ripple and causes a slight increase in output voltage as seen in figures 8 and 9. Another effect of reduced  $f_s$  at light load is slow down of transient response when a load step transitions from a high load to a light load. This is shown in figures 16 and 17.

## APPLICATION INFORMATION

### SETTING THE OUTPUT VOLTAGE

Use an external resistor divider to set the output voltage. Program the output voltage from:

$$R1 = R2 \times \left( \frac{V_{OUT}}{0.8} - 1 \right)$$

where:

R1 is the resistor between  $V_{OUT}$  and FB

R2 is the resistor between FB and GND (nominally 2k $\Omega$ )

0.8V is the nominal feedback voltage.

### FEED-FORWARD CAPACITOR CFF

CFF, which is placed in parallel with R1, provides a low-impedance/high-frequency path for the output voltage ripple to be transmitted to FB. It also helps get an optimum transient response. An initial value for CFF can be calculated from:

$$CFF = \frac{1}{2 \times \pi \times f_s \times 0.1 \times R1}$$

where:

$f_s$  is the switching frequency from table 2

This value can be adjusted as necessary to provide an optimum load step transient response.



**OUTPUT INDUCTOR**

Select the output inductor L1 for inductance L, DC current rating  $I_{DC}$  and saturation current rating  $I_{SAT}$ .  $I_{DC}$  should be larger than regulator output current.  $I_{SAT}$ , as a rule of thumb, should be 50% higher than the regulator output current. Calculate the inductance from:

$$L = (V_{IN} - V_{OUT}) \left( \frac{V_{OUT}}{\Delta I_L \times f_s \times V_{IN}} \right)$$

Where:

$\Delta I_L$  is peak-to-peak inductor current ripple nominally set to 30% of  $I_{OUT}$

$f_s$  is nominal switching frequency from table 2

**OUTPUT CAPACITOR  $C_{OUT}$** 

Select the output capacitor for voltage rating, capacitance  $C_{OUT}$  and Equivalent Series Resistance ESR. The voltage rating, as a rule of thumb, should be twice the output voltage. When calculating the required capacitance, usually the overriding requirement is current load-step transient. If the unloading transient requirement (i.e., when  $I_{OUT}$  transitions from a high to a low current) is met, then usually the loading transient requirement (when  $I_{OUT}$  transitions from a low to a high current) is met as well. Therefore calculate the  $C_{OUT}$  capacitance based on the unloading transient requirement from:

$$C_{OUT} = L \times \left( \frac{I_{High}^2 - I_{LOW}^2}{(V_{OUT} + V_{transient})^2 - V_{OUT}^2} \right)$$

Where:

L is the inductance calculated in the preceding step

$I_{High}$  is the value of  $I_{OUT}$  prior to unloading. This is nominally set equal to regulator current rating.

$I_{LOW}$  is the value of  $I_{OUT}$  after unloading. This is nominally set equal to 50% of regulator current rating.

$V_{transient}$  is the maximum permissible voltage transient corresponding to the load step mentioned above.  $V_{transient}$  is typically specified from 3% to 5% of  $V_{OUT}$ .

ESR of the capacitor has to be selected such that the output voltage ripple requirement  $V_{OUT(ripple)}$ , nominally 1% of  $V_{OUT}$ , is met. Voltage ripple  $V_{OUT(ripple)}$  is composed mainly of two components: the resistive ripple due to ESR and capacitive ripple due to  $C_{OUT}$  charge transfer. For applications requiring low voltage ripple, ceramic capacitors are recommended because of their low ESR which is typically in the range of 5m $\Omega$ . Therefore  $V_{OUT(ripple)}$  is mainly capacitive. For ceramic capacitors calculate the  $V_{OUT(ripple)}$  from:

$$V_{OUT(ripple)} = \frac{\Delta I_L}{8 \times C_{OUT} \times f_s}$$

Where:

$C_{OUT}$  is the value calculated above

If tantalum or electrolytic capacitors are used then  $V_{OUT(ripple)}$  is essentially a function of ESR:

$$V_{OUT(ripple)} = \Delta I_L \times ESR$$

**INPUT CAPACITOR  $C_{IN}$** 

Select the input capacitor for voltage rating, RMS current rating and capacitance. The voltage rating, as a rule of thumb, should be 50% higher than the regulator's maximum input voltage. Calculate the capacitor's current rating from:

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

Where:

$I_{OUT}$  is regulator's maximum current

D is duty cycle ( $D = V_{OUT}/V_{IN}$ )

Calculate the  $C_{IN}$  capacitance from:

$$C_{IN} = \frac{I_{OUT} \times V_{OUT} \times (V_{IN} - V_{OUT})}{f_s \times V_{IN}^2 \times \Delta V_{IN}}$$

Where:

$\Delta V_{IN}$  is the permissible input voltage ripple, nominally set to 1% of  $V_{IN}$ .

**TYPICAL APPLICATIONS**

**12V TO 3.3V / 3A CONVERSION**

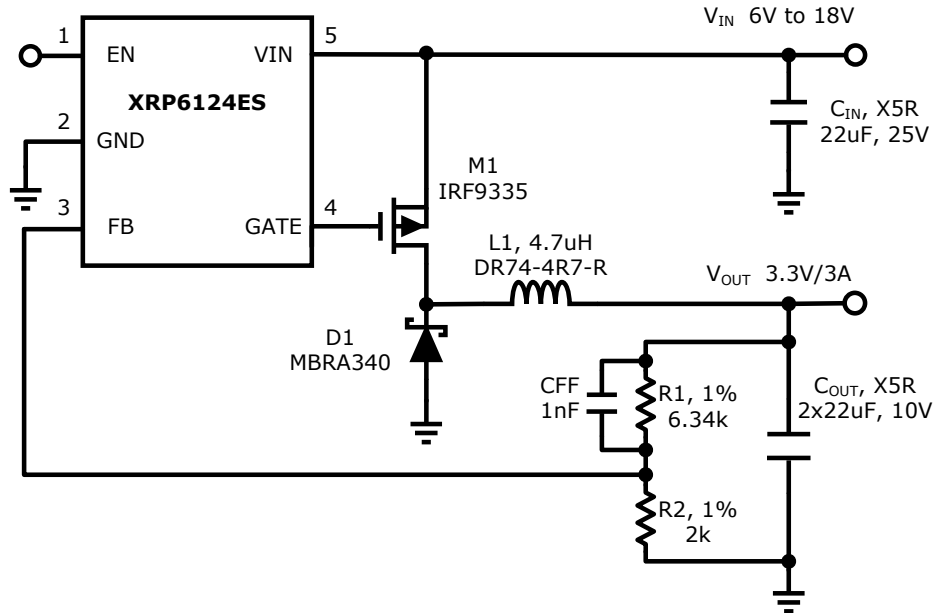


Fig. 20: 12V to 3.3V/3A regulator

**24V TO 5V / 3A CONVERSION**

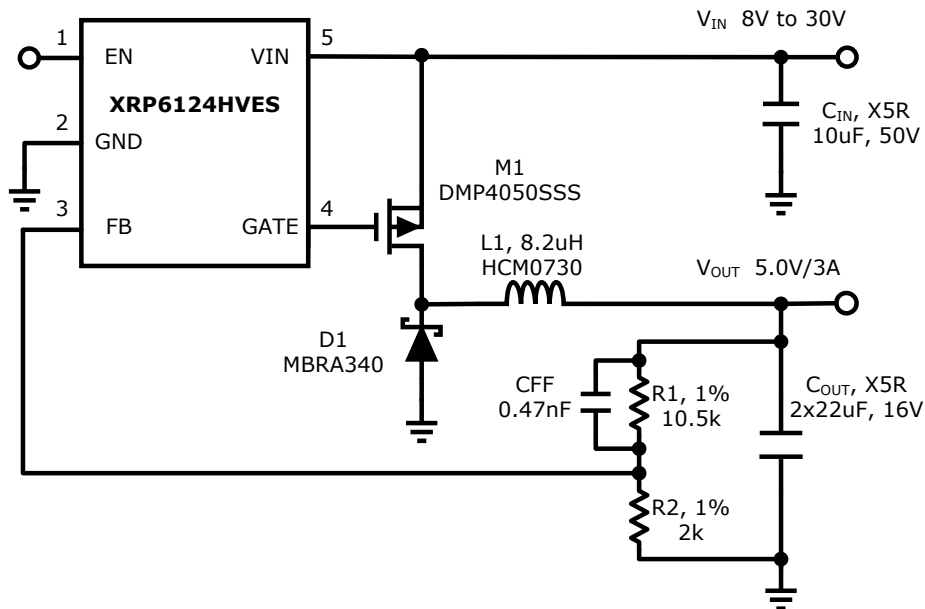
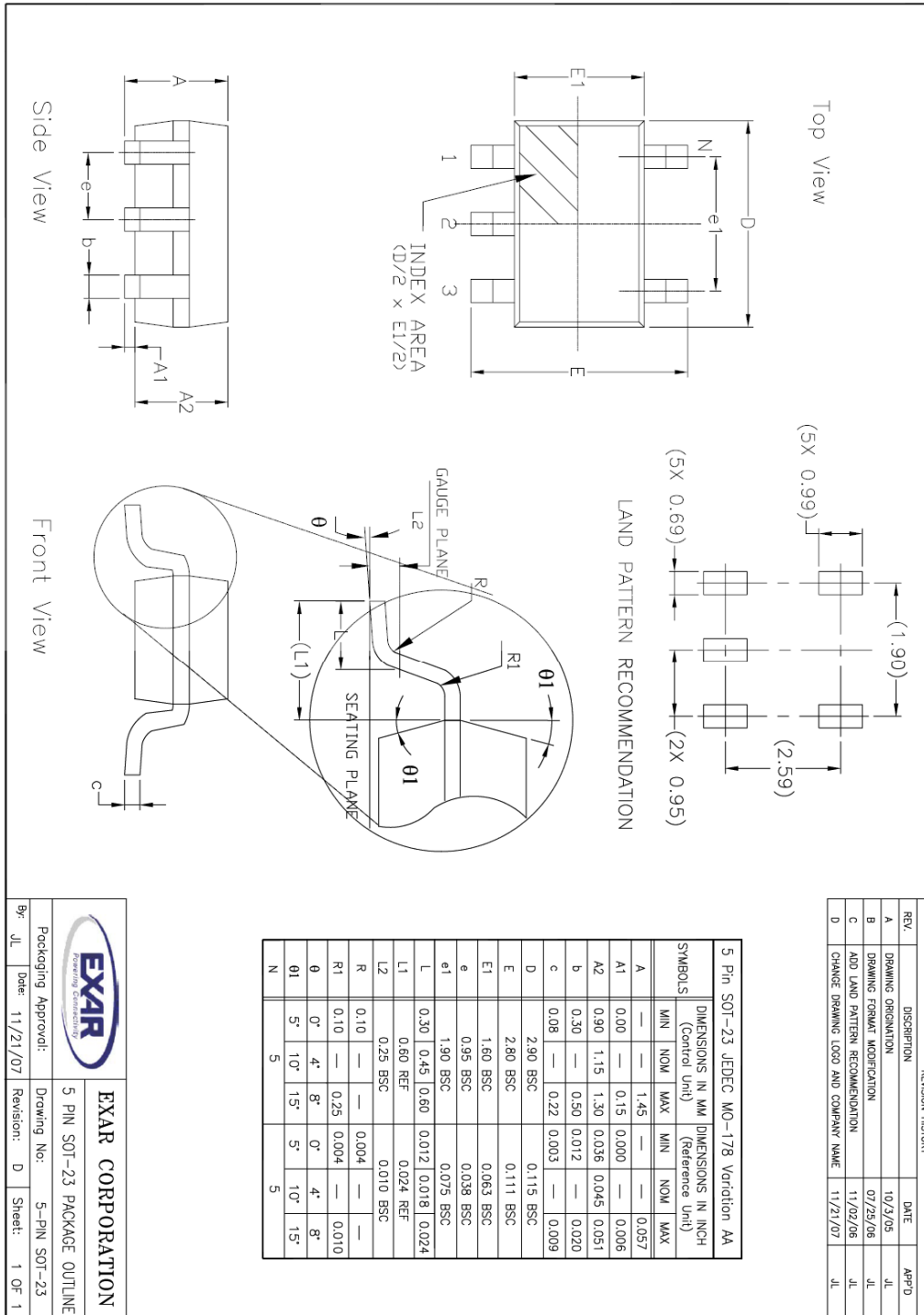


Fig. 21: 24V to 5V/3A regulator

**PACKAGE SPECIFICATION**

**5-PIN SOT23**





**REVISION HISTORY**

Revision	Date	Description
1.0.0	01/26/2011	Initial release of datasheet
1.1.0	01/31/2011	Corrected typo (changed V to I) on formula under Input Capacitor C <sub>IN</sub> paragraph

**FOR FURTHER ASSISTANCE**

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