# 150KHz, 36V, 5A CC/CV Mode Synchronous Step-Down Converter

## Features

- Up to 5A output Current
- Wide Input Voltage Range: 4.5V to 36V
- Excellent Line and Load Transient Responses
- Integrated 40mΩ N-Channel MOSFET for High Side
- Integrated 15mΩ N-Channel MOSFET for Low Side
- Fixed 150KHz Frequency
- CC/CV Mode Control
- Adjustable Soft-Start
- Programmable Cable Compensation
- Cycle-by-Cycle Current Limit
- Hiccup Short Circuit Protection
- Over-Temperature Protection

## Applications

- Car Charger
- Portable Charger Application
- DC-DC Converter with Current Limit

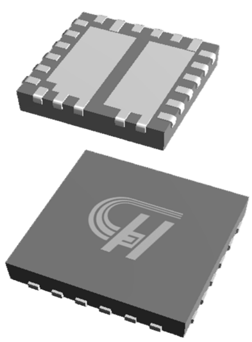
## General Description

The HCR3237 is a synchronous, step-down constant on-time buck regulator capable of driving 5A continuous load current. The HCR3237 operates in either CC (Constant Current) mode or CV(Constant Voltage)mode with an input voltage range from 4.5V to 36V. The HCR3237 provides programmable cable compensation by adjusting external resistor divider. The HCR3237 prodives excellent transient response with constant on-time control method while maintaining a nearly constant frequency of 150KHz.

Fault condition protection includes VIN under-voltage lockout, cycle-by-cycle current limiting, short-circuit protection, as well as thermal shutdown.Programmable soft-start minimizes the inrush supply current and the output overshoot at initial startup.

The HCR3237 is available in TQFN-4X4-23L package.

RoHS Compliant & 100% Lead(pb)-Free Halogen-Free



TQFN-4X4-23L

**Figure 1. Package Type of HCR3237**

## Pin Configuration

TQFN-4X4-23L ( Top View )

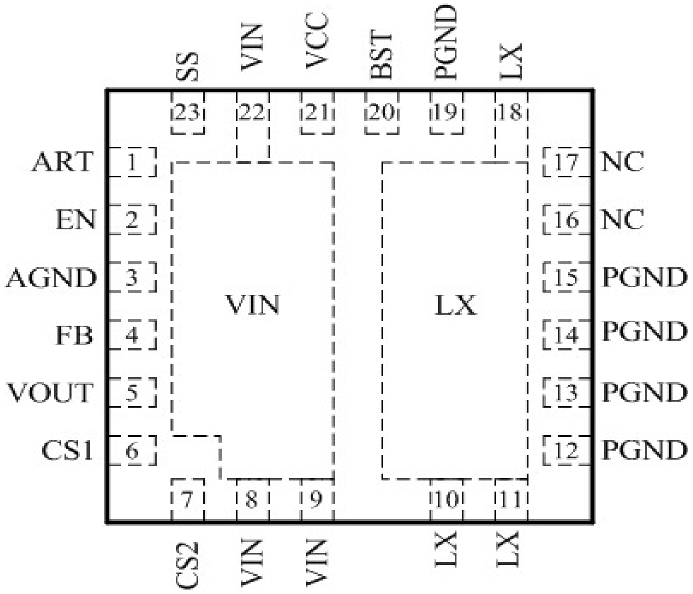



Figure 2. Pin Configuration of HCR3237 (Top View )

## Pin Function Table

| Pin | Name | Function |
|---|---|---|
| 8,9,22,Left Exposed Pad | VIN | Power Supply input pin. |
| 23 | SS | Soft start time setting pin, Connect a capacitor to ground to set the soft start time |
| 1 | ART | Hiccup time setting pin. Connect ART to AGND with a capacitor to set hiccup time |
| 2 | EN | Enable pin. Chip is enabled when EN=1, Shutdown when EN=0 |
| 3 | AGND | Signal ground pin. |
| 4 | FB | Output Voltage feedback pin |
| 5 | VOUT | Output Voltage pin |
| 6 | CS1 | Channel one current sense pin |
| 7 | CS2 | Channel two current sense pin |
| 10,11,18,Right Exposed Pad | LX | Swithing output pin |
| NA | CGND | Current sense ground pin |
| NA | LGATE | Low-side switch drive pin |
| 12,13,14,15,19 | PGND | Power ground pin |
| 20 | BST | Bootstrap capacitor connection pin. BST is power supply for high side gate driver. Connect an external capacitor between BST and LX |
| 21 | VCC | 5V LDO output pin, Connect a 1uF ceramic capacitor between VCCA and AGND |
| 16,17 | NC | Not connected |

## Functional Block Diagram

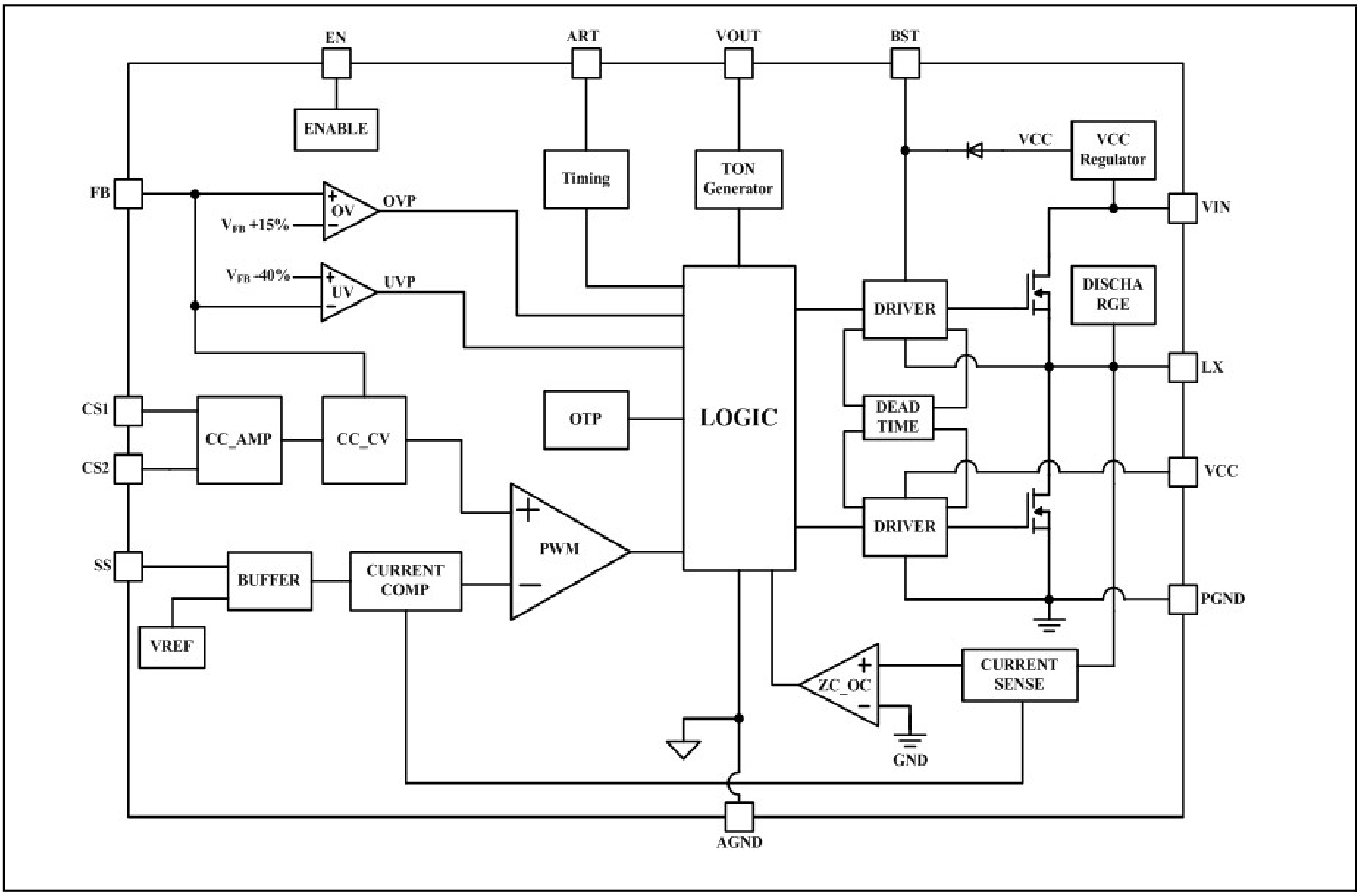



**Figure 3. Functional Block Diagram of HCR3237**

## Ordering Information

HCR3237 / □ □ □

- Circuit Type: HCR3237
- ADJ: Adjustable Output
- Package: TN23L: TQFN-4X4-23L
- TR : Tape and Reel

## Ordering Code

| Part Number | Marking Id[notea] | Temperature Range | Package | Quantity per Reel |
|---|---|---|---|---|
| HCR3237/ADJTN23LTR | HCR3237 XXXX | -40'C to +85'C | TQFN-4X4-23L | 2500pcs/TR |

Notea:The XXXX is Year and Month code.

## Absolute Maximum Ratings Note 1

| Parameter | Symbol | Value | Unit |
|---|---|---|---|
| Supply Input Voltage | VIN | -0.3 to +40 | V |
| Enable Voltage | VEN | -0.3 to +40 | V |
| Switch Voltage | VLX | -1 to VIN +0.3 | V |
| Bootstrap Voltage | VBST | VLX-0.3 to VLX +6 | V |
| Output Voltage | VOUT | -0.3 to 30 | V |
| All Other Pins | - | -0.3 to +6 | V |
| Thermal Resistance Junction to Ambient | RθJA | 45 | 'C/W |
| Thermal Resistance Junction to Case | RθJC | 4.5 | 'C/W |
| Storage Temperature Range | TSTG | -65 to 150 | 'C |
| Operating Junction Temperature | TJ | -40 to 150 | 'C |
| Lead Temperature (Soldering, 10s) | TLEAD | 260 | 'C |

## Recommend Operating Conditions note2

| Parameter | Symbol | Value | Unit |
|---|---|---|---|
| Input Voltage | VIN | 4.5 to 36 | V |
| Ambient Operting Temp | TA | -40 to +85 | 'C |

Note 1: Stresses beyond those listed under"Absolute maximum Ratings" may damage the device.

2: The device is not guaranteed to function outside the recommended operating conditions.

## Electrical Characteristics

The specifications which apply over the full operating temperature range, otherwise specification are VIN=12V, VEN=5V ( Ta=25'C; unless otherwise specified )

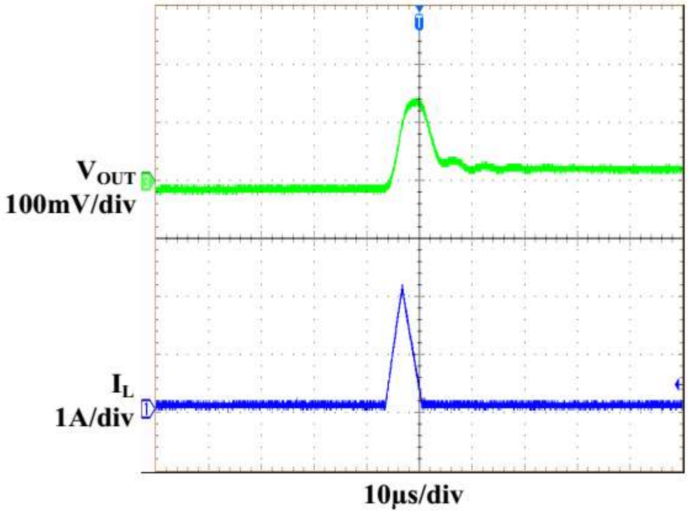
| Parameter | Symbol | Test Condition | Min | Type | Max | Unit |
|---|---|---|---|---|---|---|
| **General Section** | | | | | | |
| Input Operation Voltage | $V_{in}$ | | 4.5 | - | 36 | V |
| Quiescent Supply Current | $I_Q$ | $V_{EN}$=5V, $V_{FB}$=0.85V | - | 1 | 2 | mA |
| Shutdown Supply Current | $I_{SD}$ | $V_{EN}$=0V | - | 3 | 5 | uA |
| **Control Section** | | | | | | |
| Enable Threshold | $V_{ENH}$ | On State | 2.5 | - | - | V |
| | $V_{ENL}$ | Off State | - | - | 0.5 | V |
| $V_{IN}$ UV Lockout threshold | $V_{UVLO}$ | $V_{IN}$ rising | - | 3.9 | 4.3 | V |
| | | $V_{IN}$ falling | 3.2 | 3.6 | - | V |
| **Modulator Section** | | | | | | |
| Oscillator Frequency | $F_{OSC}$ | $V_{IN}$=12V | 120 | 150 | 180 | KHz |
| Minimum On Time | $T_{on\_MIN}$ | | - | 100 | - | ns |
| Minimum Off Time | $T_{off\_MIN}$ | | - | 400 | - | ns |
| Feedback Voltage | $V_{FB}$ | | 0.788 | 0.800 | 0.812 | V |
| CS1/CS2 reference voltage | $V_{CS}$ | | 101 | 108 | 115 | mV |
| Cable Compensation | $I_{Cable}$ | $V_{CS}$=0.1V | - | 2.7 | - | uA |
| **Power MOS Section** | | | | | | |
| High-side MOS On-Resistance | $R_{DSONH}$ | $V_{IN}$=12V | - | 40 | - | mΩ |
| Low-side MOS On-Resistance | $R_{DSONL}$ | $V_{IN}$=12V | - | 15 | - | mΩ |
| **Soft Start and Hiccup Section** | | | | | | |
| Internal Soft Start Current | $I_{SS}$ | $V_{SS}$=0V | - | 10 | - | uA |
| Internal Hiccup Charging Current | $I_{ART}$ | - | - | 2.5 | - | uA |
| **Protection Section** | | | | | | |
| Valley Current of $I_L$ | $I_{OCP}$ | - | 6 | - | - | A |
| UVP Threshold | $V_{UV}$ | FB Falling | 55 | 60 | 65 | % |
| UVP Delay Time | $T_{UV}$ | FB Falling | - | 1 | - | ms |
| OVP Threshold | $V_{OV}$ | FB Rising | 112 | 115 | 118 | % |
| OVP Delay Time | $T_{OV}$ | FB Rising | - | 10 | - | us |
| Minimum On Time | $T_{on}$ | | - | 220 | - | ns |
| Thermal Shutdown Threshold | $T_{SD}$ | | - | 160 | - | 'C |
| Thermal Shutdown Hysteresis | $T_{SD\_HYS}$ | | - | 60 | - | 'C |

## Typical Performance Characteristics

**(VIN=12V, VOUT=5V, f=150KHz, TA=+25'C, unless otherwise specified)**

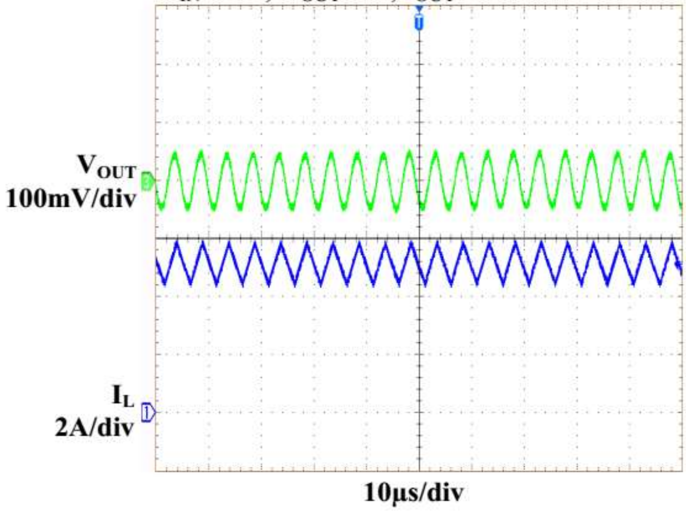
**Steady State**

$V_{IN}$=12V, $V_{OUT}$=5V, No Load



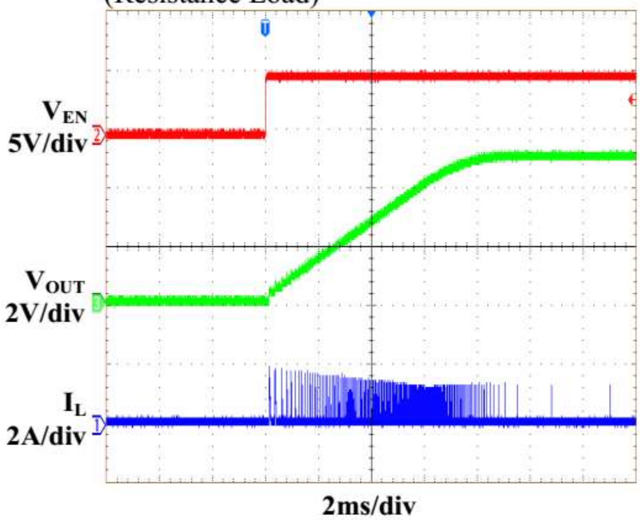

**Steady State**

$V_{IN}$=12V, $V_{OUT}$=5V, $I_{OUT}$=5A



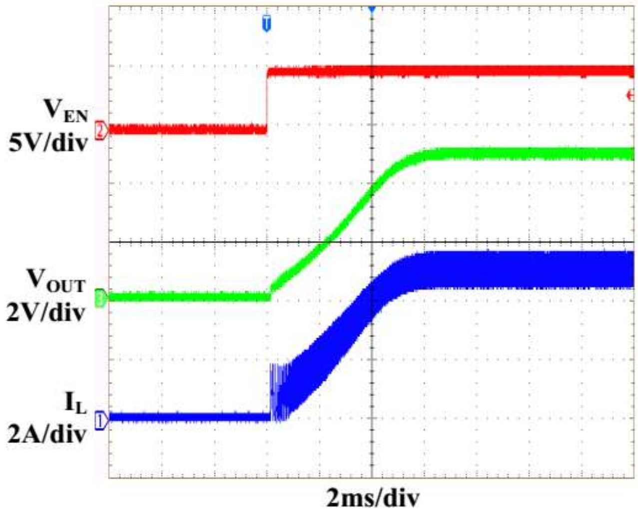

**Startup through Enable**

$V_{IN}$=12V, $V_{OUT}$=5V, $C_{SS}$=100nF, $I_{OUT}$=0A (Resistance Load)



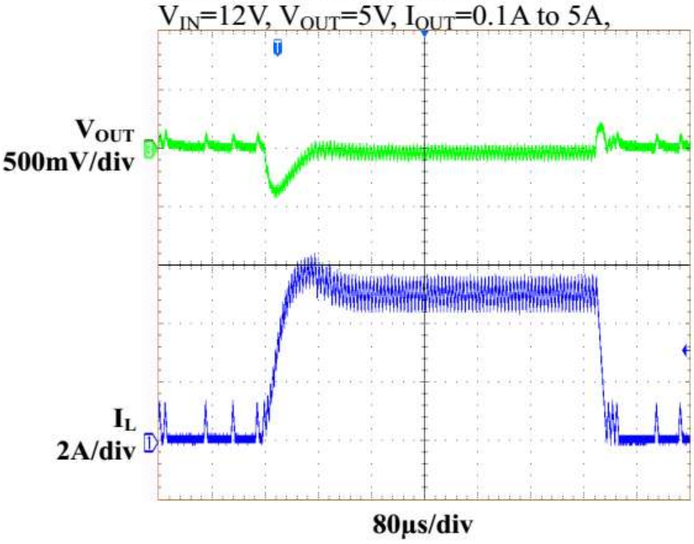

**Startup through Enable**

$V_{IN}$=12V, $V_{OUT}$=5V, $C_{SS}$=100nF, $I_{OUT}$=5A (Resistance Load)



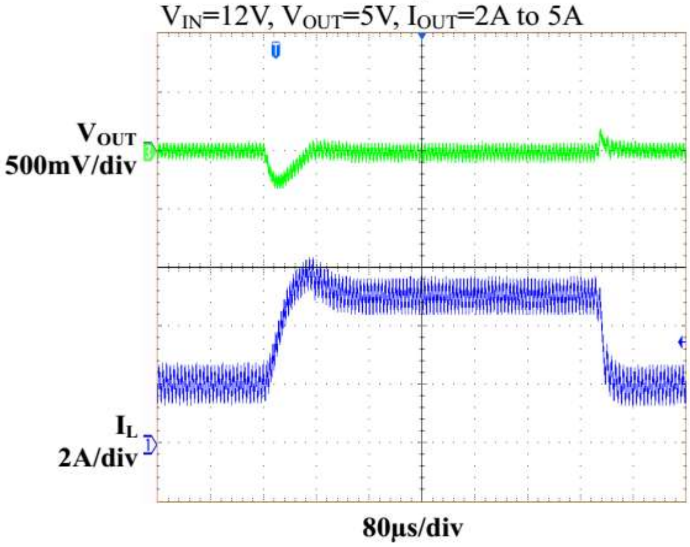

**Load Transient Response**

$V_{IN}$=12V, $V_{OUT}$=5V, $I_{OUT}$=0.1A to 5A,




**Load Transient Response**

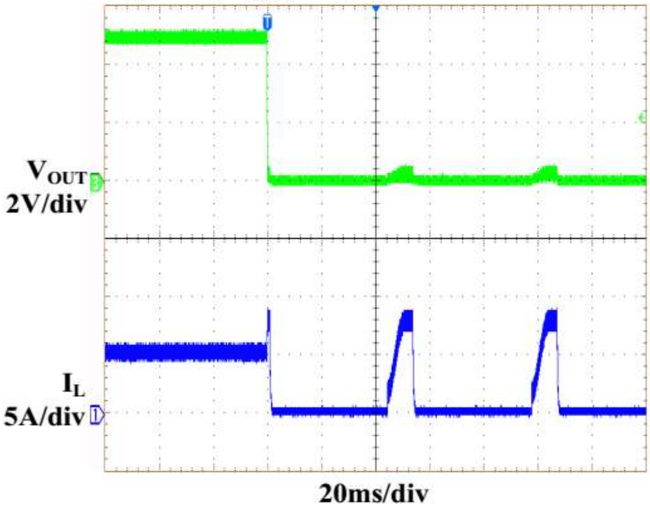
$V_{IN}$=12V, $V_{OUT}$=5V, $I_{OUT}$=2A to 5A



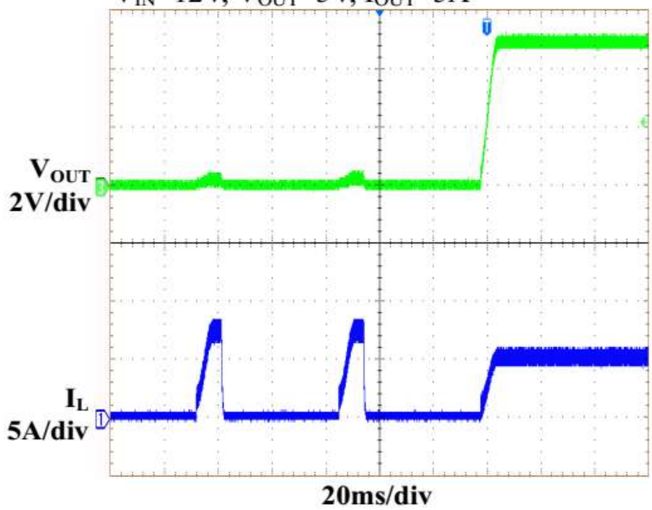
## Typical Performance Characteristics (continued)

**(VIN=12V, VOUT=5V, f=150KHz, TA=+25'C, unless otherwise specified)**

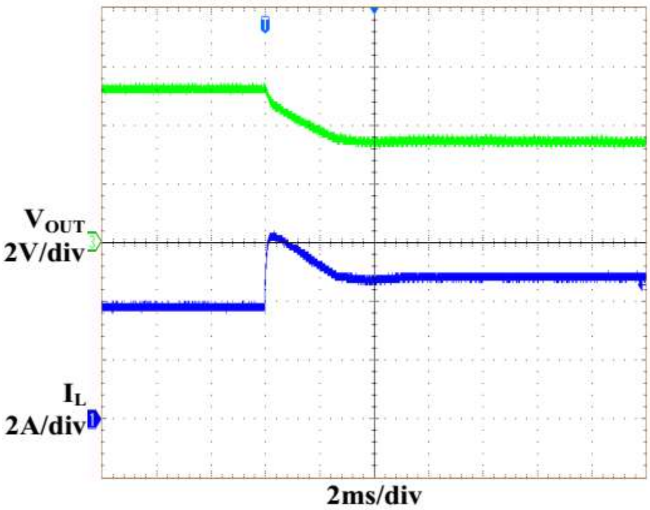
**Short Circuit**
$V_{IN}$=12V, $V_{OUT}$=5V, $I_{OUT}$=5A



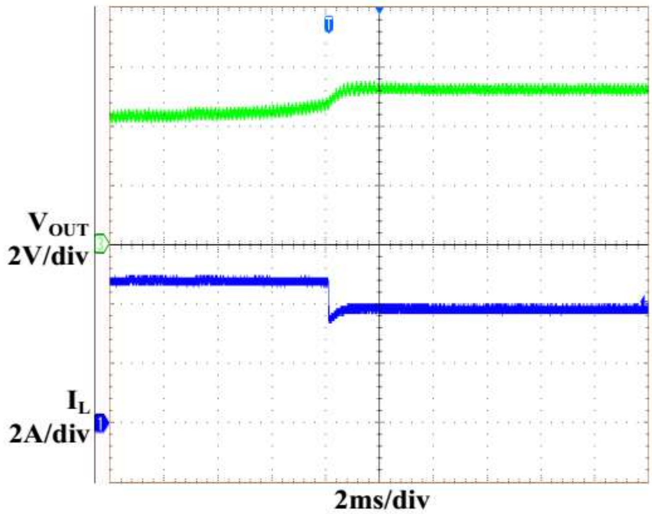

**Short Circuit Recovery**
$V_{IN}$=12V, $V_{OUT}$=5V, $I_{OUT}$=5A



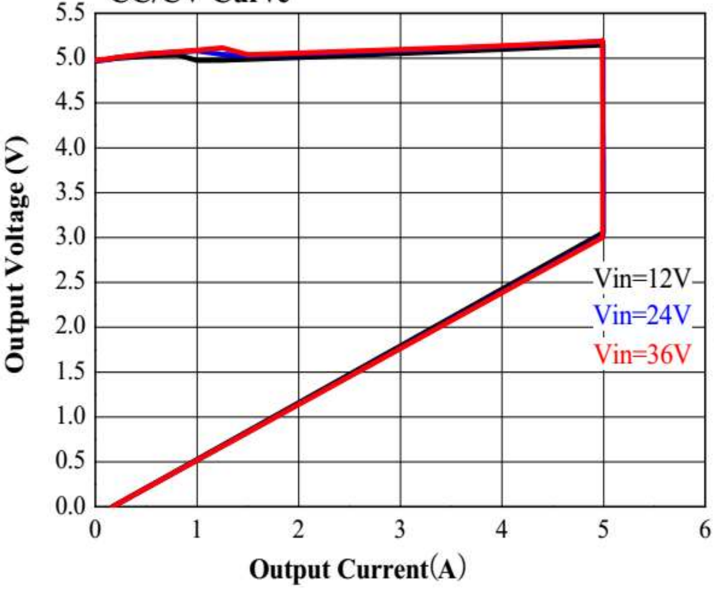

**CV mode to CC mode**
$V_{IN}$=12V, $V_{OUT}$=5V, $R_{CS}$=45mΩ, $I_{OUT}$=2A



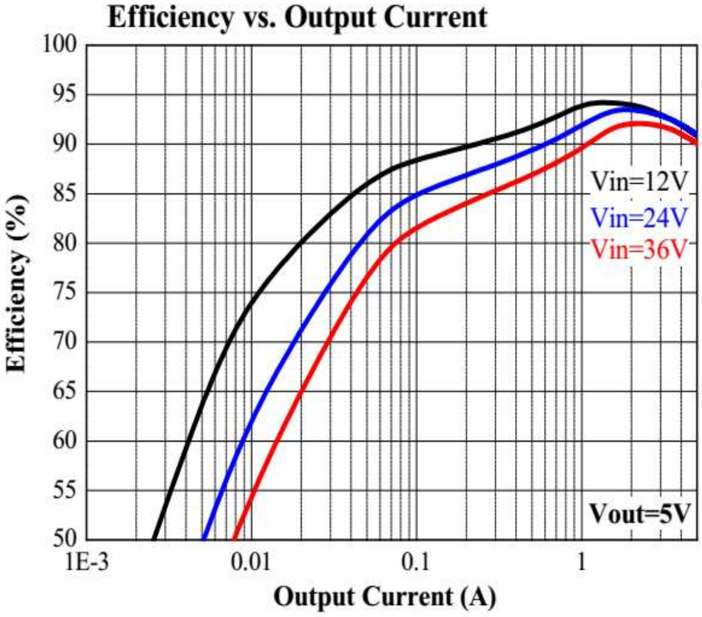

**CC mode to CV mode**
$V_{IN}$=12V, $V_{OUT}$=5V, $R_{CS}$=45mΩ, $I_{OUT}$=2A




**CC/CV Curve**




**Efficiency vs. Output Current**



## Typical Application Circuit

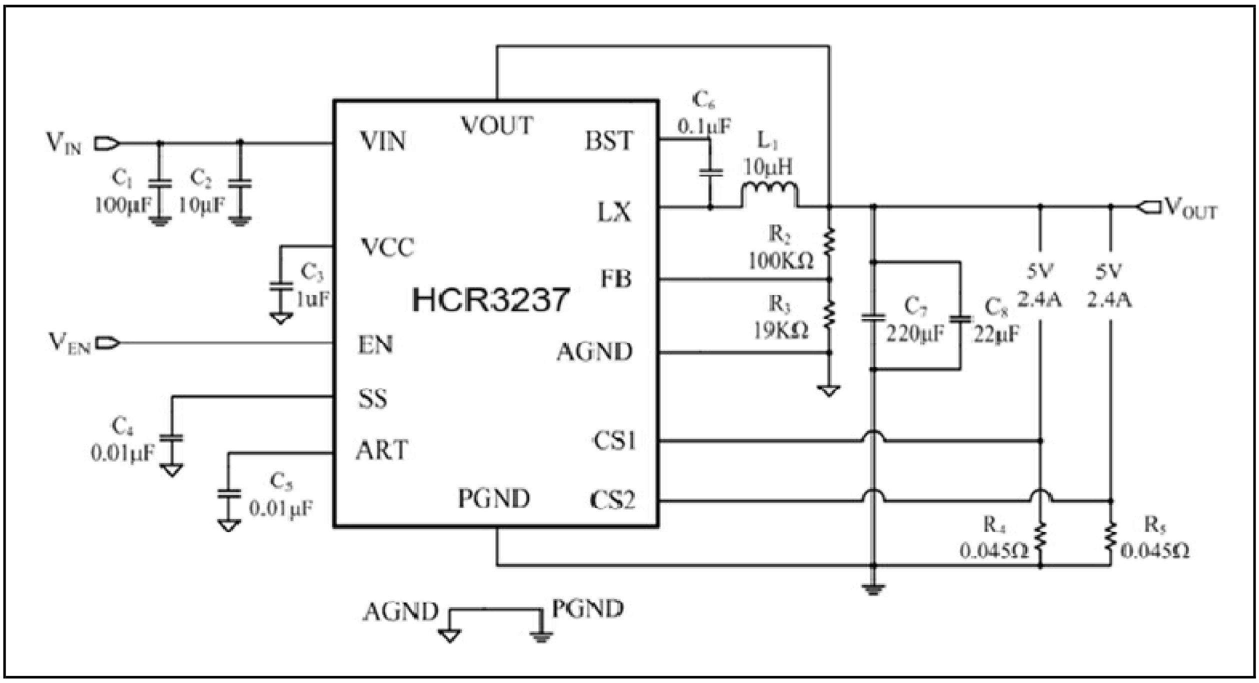



Figure 4. Adjustable Output Voltage of HCR3237

## Function Description

The HCR3237 is a constant on-time synchronous step-down converter with 4.5V to 36V input power supply. The device can provide up to 5A continuous current to the output. This architecture provides very fast on-time response to output load transients. The switching frequency is 150KHz.

The converter uses internal N-Channel MOSFET switches to step-down the input voltage to the regulated output voltage. Since the high side MOSFET requires a gate voltage greater than the input voltage a boost capacitor connected between LX and BST is needed to drive the high side gate. The bootstrap capacitor is charged from the internal 5V rail when LX is Low. At light loads, the inductor current may reach zero or reverse on each pulse. The bottom MOS is turned off by the current reversal comparator and the switch voltage will ring. This is discontinuous mode operation, and is normal behavior for the switching regulator. At light load, the HCR3237 will automatic-ally skip pulses in pulse skipping mode operation to maintain output regulation and increases efficiency.

### CC/CV mode control

The HCR3237 operates in either CC mode or CV mode The CV mode regulates the output voltage. When output current reaches the CC threshold, the device enters CC mode to limit the output current.

The accurate CC current is implemented by the CS1 and CS2 pins, which can be set by the following equation:

$$I_{CS}(A) = 108(mV) / R_4(m\Omega)$$

### Programmable Cable Compensation

The HCR3237 provides programmable cable compensation by adjusting the external resistor divider to compensate resistive voltage drop across the charger's output cable. The cable compensation voltage can be expressed as:

$$\Delta V_{OUT}(mV) = 0.037 \times \left(I_{OUT}(A) \times R_4(\Omega)\right) \times R_2(\Omega)$$

By adjust the value of R2, the cable compensation voltage can be programmed.

## Function Description(Con.)

### Soft Start

The HCR3237 has external soft start feature to minimize the inrush supply current and the output overshoot at initial startup. An internal current source, which is typical 10uA, charges the external soft-start capacitor. The soft-start time(TSS) and can be calculated by the following formula: $T_{SS}(ms) = 0.1 \times C_4(nF)$

### Over Current Protection

If the sensed current value is above the OC setting, the converter delays the next ON pulse until the current drops below the OC limit. Current limiting occurs on a pulse-by-pulse basis. The HCR3237 uses a valley current limiting scheme where the DC current point is the OC limit plus half of the inductor ripple current. The minimum valley OC limit is 6A over process and temperature.

$$I_{OC}(DC) = I_{OC}(valley) + \frac{1}{2} \times I_{Peak-to-Peak}$$

### Over Voltage Protection

OVP (over voltage protection) function with fixed 0V (over voltage) threshold set by the internal resistor divider is provided. When the FB pin voltage exceeds

### Over Voltage Protection(con.)

15% of the nominal regulation value of 0.8V, the high--side switch turns off and low-side switch turns on cycle-by-cycle until the output over voltage is released.

### Under Voltage Protection

UVP (under voltage protection) function continually monitors the FB voltage after soft-start is completed. If output voltage is lower than 60% of the nominal output voltage by over current or short circuit, the device will wait 1ms and enters hiccup mode. In hiccup mode, there is a dealy time period before restart,which can be set by connecting a capacitor from ART pin to AGND pin. A current will charge the capacitor from ground level to a preset level. The delay time is calculated by the following equation:

$$T_{HICCUP}(ms) = 0.445 \times C_5(nF)$$

### Thermal Shutdown

The HCR3237 stops switching when its junction temperature exceeds 160'C and resumes when the temperature has dropped by 60'C to protect the device.

## Application Information

### Setting the Output Voltage

The output voltage is set through a resistive voltage divider and can be expressed by the equation as follows

$$V_{OUT} = 0.8 \times \frac{R3 + R4}{R4}$$

### Inductor

The inductor is required to supply constant current to the load while being driven by the switched input voltage. A larger value inductor will result in less ripple current that will in turn result in lower output ripple voltage. However, the larger value inductor will have a large physical size, higher series resistance, and/or lower saturation current. A good rule for determining inductance is to allow the peak-to-peak ripple current to be approximatelly 30% of the maximum switch current limit. Also, make sure that the peak inductor current is below the maximum switch current limit. The inductance value can be calculated by:

$$L = \frac{V_{OUT}}{f_{LX} \times \Delta I_L} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

### Inductor (Con.)

Where $V_{OUT}$ is the output voltage, $V_{IN}$ is the input voltage, $f_{LX}$ is the switching frequency, and $\Delta I_L$ is the peak-to-peak inductor ripple current.

Choose an inductor peak current, calculated by:

$$I_{LP} = I_{LOAD} + \frac{V_{OUT}}{2 \times f_{LX} \times L} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

Where $I_{LOAD}$ is the load current.

The choice of which style inductor to use mainly depends on the price vs.size requirements and any EMI constraints.

### Input Capacitor

The input current to the step-down converter is discontinuous, therefore a capacitor is required to supply the AC current while maintaining the DC input voltage. Use low ESR capacitors for the best perform--ance. Ceramic capacitors are preferred, but tantalum or low-ESR electrolytic capacitors will also suffice. Choose X5R or X7R dielectrics when using ceramic

## Application Information(Con,)

### Input Capacitor(Con.)

capacitors. Since the input capacitor (C1) absorbs the input switching current, it requires an adequate ripple current rating. The RMS current in the input capacitor can be estimated by:

$$I_{C1} = I_{LOAD} \times \sqrt{\frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)}$$

The worst-case condition occurs at $V_{IN}=2V_{OUT}$, where $I_{C1}=I_{LOAD}/2$. For simplification, use an input capacitor with a RMS current rating greater than half of the maximum load current.

The input capacitor can be electrolytic, tantalum or ceramic,When using electrolytic or tantalum capacitors, a small, high quality ceramic capacitor, i.e.0.1uF,should be placed as close to the IC as possible. When suing ceramic capacitors, make sure that they have enough capacitance to provide sufficient charge to prevent excessive voltage ripple at input. The input voltage ripple for low ESR capacitors can be estimated by:

$$\Delta V_{IN} = \frac{I_{LOAD}}{C_1 \times f_{LX}} \times \frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

Where C1 is the input capacitance value.

For simplification, choose the input capacitor whose RMS current rating greater than half of the maximum load current.

### Output Capacitor

The output capacitor(C5) is required to maintain the DC output voltage. Ceramic, tantalum, or low ESR electrol--ytic capacitors are recommended. Low ESR capacitors are preferred to keep the output voltage ripple low. The output voltage ripple can be estimated

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_{LX} \times L} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times \left(R_{ESR} + \frac{1}{8 \times f_{LX} \times C_5}\right)$$

Where C2 is the output capacitance value and $R_{ESR}$ is the equivalent series resistance ( ESR ) value of the output capacitor.

when using ceramic capacitors, the impedance at the switching frequency is dominated by the capacitance which is the main cause for the output voltage ripple. for simplification, the output voltage ripple can be estimated by:

$$\Delta V_{OUT} = \frac{V_{OUT}}{8 \times f^2_{LX} \times L \times C_5} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

When using tantalum or electrolytic capacitors, the ESR dominates the impedance at the switching frequency. For simplification, the output ripple can be

### Output Capacitor(Con.)

approximated to:

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_{LX} \times L} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times R_{ESR}$$

The characteristics of the output capacitor also affect the stability of the regulation system. The HCR3237 Can be optimized for a wide range of capacitance and ESR values.

### Thermal Considerations

To avoid the HCR3237 from exceeding the maximum junction temperature,the user will need to do a thermal analysis. The goal of the thermal analysis is to determine whether the operating conditions exceed the maximum junction temperature of the part. The temperature rise is given by:

$$T_R = P_D \times \theta_{JA}$$
$$= \left(V_{IN} \times I_{IN} - V_{OUT} \times I_{OUT} - I^2_{OUT} \times R_{DCR}\right) \times \theta_{JA}$$

Where $P_D$ is the power dissipated by the regulator, $\theta_{JA}$ is the thermal resistance from the junction of the die to the ambient temperature; $R_{DCR}$ is resistor of inductor. Then the junction temperature, TJ is give by:

$$T_J = T_A \times T_R$$

Where TA is the ambient temperature.

### PC Board Layout Checklist

For all switching power supplies, the layout is an important step in the design especially at high peak currents and switching frequencies. If the layout is not carefully done, the regulator might show stability problems as well as EMI problems. When laying out the printed circuit board, the following guidelines should be used to ensure proper operation of the HCR3237.

1.1 The input capacitor C1 should connect to VIN as closely as possible. This capacitor provides the AC current to the internal power MOSFETs.

1.2 The power traces,consisting of the PGND trace, the LX trace and the VIN trace should be kept short, direct and wide.

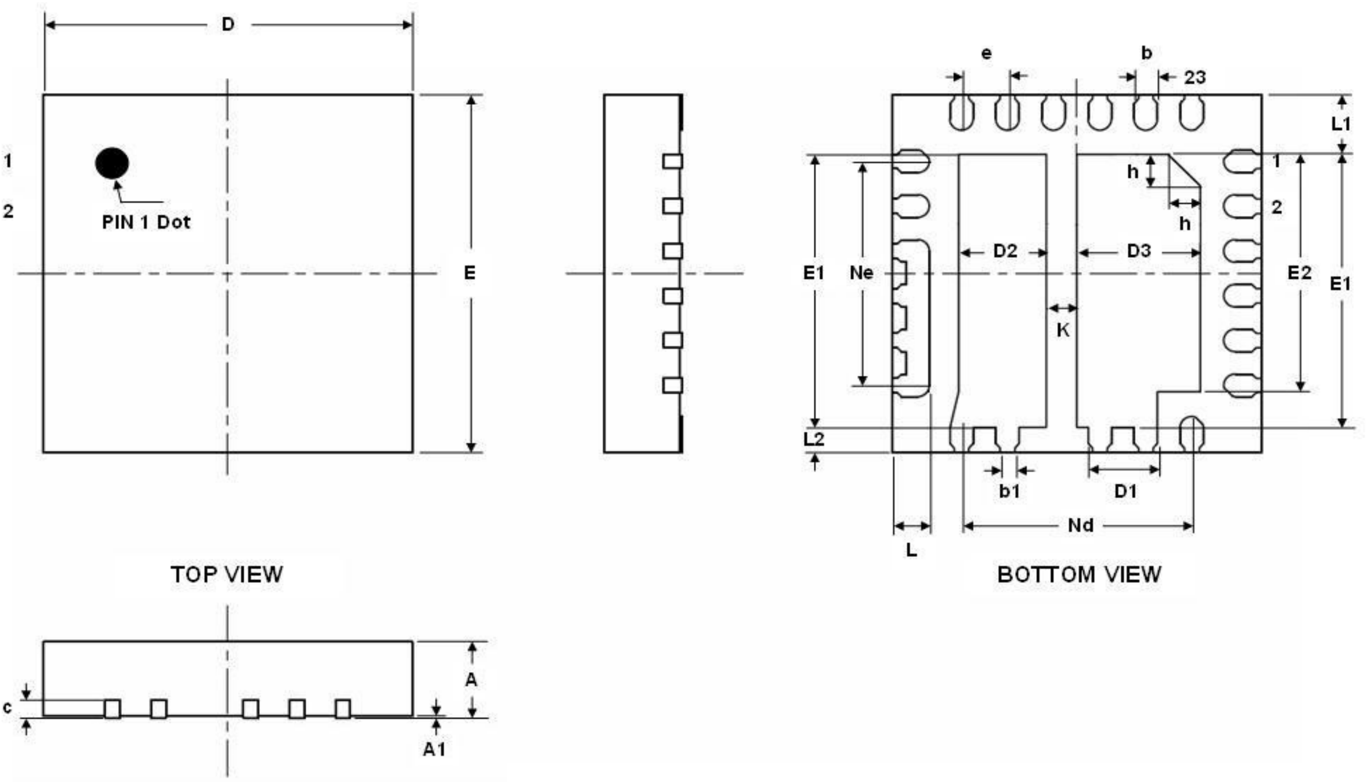
1.3 The VOUT pin should connect directly to the inductor output. The resistive divider R2/R3 must be connected as close as possible between the FB and AGND

1.4 Keep the switching node, LX, away from the sensitive VOUT/FB node.

## Mechanical Dimensions

**PKG: TQFN-4X4-23L**

**Unit: mm( inch )**




Note: The exposed pad outline drawing is for reference only.

| SYMBOLS | MILLIMETERS | | | INCHES | | |
|---|---|---|---|---|---|---|
| | MIN. | Normal | MAX. | MIN. | Normal | MAX. |
| A | 0.70 | 0.75 | 0.80 | 0.028 | 0.030 | 0.032 |
| A1 | 0.00 | 0.02 | 0.05 | 0.000 | 0.001 | 0.002 |
| b | 0.20 | 0.25 | 0.30 | 0.008 | 0.010 | 0.012 |
| b1 | 0.16 REF | | | 0.006 REF | | |
| D | 3.90 | 4.00 | 4.10 | 0.154 | 0.157 | 0.161 |
| D1 | 0.65 | 0.75 | 0.85 | 0.026 | 0.030 | 0.033 |
| D2 | 0.85 | 0.95 | 1.05 | 0.033 | 0.037 | 0.041 |
| D3 | 1.24 | 1.34 | 1.44 | 0.049 | 0.053 | 0.057 |
| e | 0.50 REF | | | 0.020 REF | | |
| Ne | 2.50 REF | | | 0.098 REF | | |
| Nd | 2.50 REF | | | 0.098REF | | |
| E | 3.90 | 4.00 | 4.10 | 0.154 | 0.157 | 0.161 |
| E1 | 2.95 | 3.05 | 3.15 | 0.116 | 0.120 | 0.124 |
| E2 | 2.60 | 2.65 | 2.70 | 0.102 | 0.104 | 0.106 |
| L | 0.35 | 0.40 | 0.45 | 0.014 | 0.016 | 0.018 |
| L1 | 0.57 | 0.62 | 0.67 | 0.022 | 0.024 | 0.026 |
| L2 | 0.23 | 0.28 | 0.33 | 0.009 | 0.011 | 0.013 |
| K | 0.33 | - | - | 0.013 | - | - |
| h | 0.30 | 0.35 | 0.40 | 0.012 | 0.014 | 0.016 |