# 600KHz, 28V, 2A Synchronous Step-Down Converter

## Features

- 4.5V to 28V Operating Input Voltage Range
- 600KHz Switching Frequency
- 2.0A Output Current
- Up to 93% efficiency
- High efficiency at light load
- Input under voltage lockout
- Start-up current run-away protection
- Over current protection and hiccup
- Thermal Protection
- Available in SOT23-6L(TSOP-6) package

## Applications

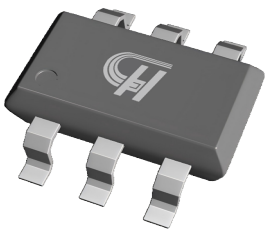
- Distributed Power Systems
- Networking Systems
- FPGA, DSP, ASIC Power Supplies
- Green Electronics/Appliances
- Notebook Computers

## General Description

The HCR3228A is a current mode monolithic buck voltage converter. Operating with an input voltage range of 4.5V-28V, the HCR3228A delivers 2A of continuous output current with two integrated N-Channel MOSFETs. At light loads, regulators operate in low frequency to maintain high efficiency.

The HCR3228A guarantees robustness with short circuit protection, thermal protection, current run-away protection, and input under voltage lockout.

The HCR3228A is available in a SOT23-6L(TSOP-6) package, which provides a compact solution with minimal external components.



SOT23-6L(TSOP-6)

Figure 1. Package Type of HCR3228A

# 600KHz, 28V, 2A Synchronous Step-Down Converter

## Pin Configuration

TSOP-6 (SOT23-6L) Top View

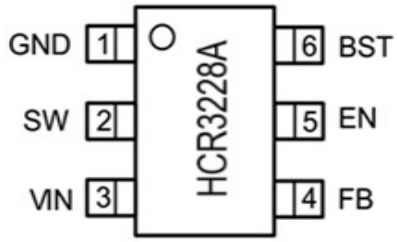
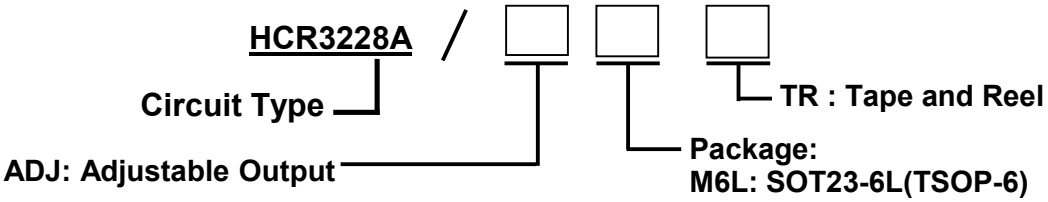



Figure 2. Pin Configuration of HCR3228A (Top View )

## Pin Function Table

| Pin Number | Pin Name | Function |
|---|---|---|
| 1 | GND | Power Ground. Must be soldered directly to ground plane. |
| 2 | SW | SW is the switching node that supplies power to the output, Contact the output LC filter from SW to the output load. |
| 3 | VIN | Input Voltage Pin. VIN supplies power to the IC. Connect a 4.5V to 28V supply to VIN and bypass VIN to GND with a suitably large capacitor to eliminate noise on the input the IC. |
| 4 | FB | Output feedback Pin. FB senses the output voltage and is regulated by the control loop to 0.6V. Connect a resistive divider at FB. |
| 5 | EN | Driver EN Pin high to turn on the regulator and low to turn off the regulator. |
| 6 | BST | Bootstrap pin for top switch. A 0.1uF or larger capacitor and a 10Ω resistor should be connected between this pin and the SW pin to supply current to the top switch and top switch driver. |

## Ordering Information




## Ordering Code

| Part Number | Marking ID note2 | Temperature Junction Range | Package | Quantity per Reel |
|---|---|---|---|---|
| HCR3228A/ADJM6LTR | *WDYXX | -40'C to +125'C | SOT23-6L (TSOP-6 ) | 3000pcs tape&Reel |

Note 2: the "XX" is Inside code.

## Absolute Maximum Ratings Note 1

| Parameter | Symbol | Value | Unit |
|---|---|---|---|
| Input Supply Voltage Range | VIN | -0.3 to +32.0 | V |
| SW Voltage Range | VSW | -0.3(-5V for 20nS) to +32.0 | V |
| BST Voltage Range | VBST | SW-0.3 to SW+5.5 | V |
| EN Voltage Range | VEN | -0.3 to +32.0 | V |
| FB Voltage Range | VFB | -0.3 to +6.0 | V |
| Power Dissipation | PO | 550 | mW |
| Thermal Resistance Junction to Ambient | RθJA | 220 | 'C/W |
| Thermal Resistance Junction to Case | RθJC | 125 | 'C/W |
| Storage Temperature Range | TSTG | -65 to 150 | 'C |
| Operating Junction Temperature | TJ | -40 to +125 | 'C |
| Lead Temperature (Soldering, 10s) | TLEAD | 260 | 'C |
| Human Body Model for all pins | VESD_HBM | ±2000 | V |
| Charge Device Model for all pins | VESD_CDM | ±500 | V |

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.

## Recommended Operating Conditions

| Parameter | Symbol | Test Condition | Min | Type | Max | Unit |
|---|---|---|---|---|---|---|
| Input Voltage Range | VIN | | 4.5 | - | 28 | V |
| Output Voltage Range | VOUT | | 0.6 | - | VIN* Dmax | V |
| Operating Junction Temperature Range | TJ | | -40 | - | +125 | 'C |

## Electrical Characteristics

($V_{IN}$=$V_{EN}$=12V, $T_A$=+25'C, unless otherwise noted.)

| Parameter | Symbol | Test Condition | Min | Type | Max | Unit |
|---|---|---|---|---|---|---|
| Input Voltage Range | $V_{IN}$ | | 4.5 | - | 28 | V |
| VIN Under Voltage Lock-out Threshold | $V_{IN\_MIN}$ | Vin rising | 3.95 | 4.2 | 4.45 | V |
| VIN Under Voltage Lock-out Hysteresis | $V_{IN\_MIN\_HYST}$ | | - | 400 | - | mV |
| Supply Current | $I_Q$ | $V_{EN}$=5V, VFB=1.2V | - | 110 | 130 | uA |
| Shutdown Supply Current | $I_{SD}$ | $V_{EN}$=0V, No load, VIN=12V | - | 1 | 3 | uA |
| Regulated Feedback Voltage Accuracy | $V_{FB}$ | -40'C<=Tj<=125'C | 588 | 600 | 612 | mV |
| High-Side Switch On Resistance | $R_{DS(ON)\_H}$ | | - | 90 | - | mΩ |
| Low-Side Switch On Resistance | $R_{DS(ON)\_L}$ | | - | 78 | - | mΩ |
| Top Switch Leakage Current | $I_{LEAK\_TOP}$ | $V_{IN}$=28V, $V_{EN}$=0V, $V_{SW}$=0V | - | 0.1 | 1.0 | uA |
| Bottom Switch Leakage Current | $I_{LEAK\_BOT}$ | $V_{IN}$=28V, $V_{EN}$=0V, $V_{SW}$=28V | - | 0.1 | 1.0 | uA |
| Top Switch Current Limit | $I_{LIM\_TOP}$ | Minimum Duty Cycle | 3.0 | 4.0 | 5.0 | A |
| Switching Frequency | $F_{SW}$ | | 450 | 600 | 750 | KHz |
| Minimum On-time | $t_{ON\_MIN}$ | - | - | 100 | - | ns |
| Minimum Off-time | $t_{OFF\_MIN}$ | $V_{FB}$=0.4V | - | 120 | - | ns |
| Enable Rising Threshold | $V_{EN-H}$ | $V_{EN}$ Rising | - | 1.20 | 1.35 | V |
| Enable Falling Threshold | $V_{EN-L}$ | $V_{EN}$ falling | 1.00 | 1.10 | - | V |
| Enable Hysteresis | $V_{EN\_HYST}$ | | - | 100 | - | mV |
| Internal Soft-Start Time | $T_{ss}$ | | - | 1 | - | ms |
| Thermal Shutdown note3 | $T_{SD}$ | | - | 150 | - | 'C |
| Thermal Hysteresis note3 | $T_{SD\_HYST}$ | | - | 20 | - | 'C |

Note 3. Thermal shutdown threshold and hysteresis are guaranteed by design.

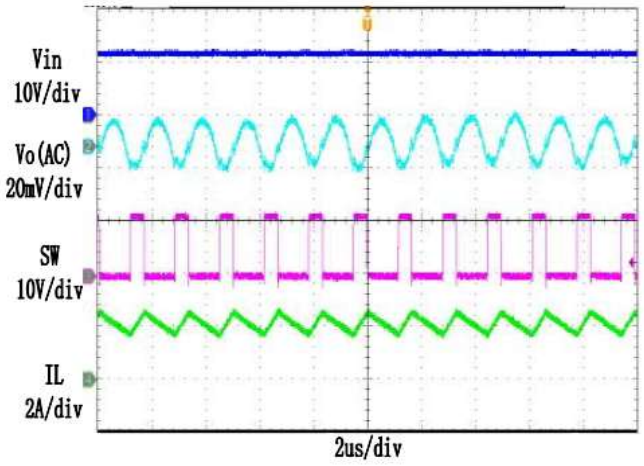
# 600KHz, 28V, 2A Synchronous Step-Down Converter

## Typical Performance Characteristics

**(Test condition: VIN=12V, VOUT=3.3V, L=4.7uH, COUT=22uF, TA=25'C, unless otherwise noted.)**

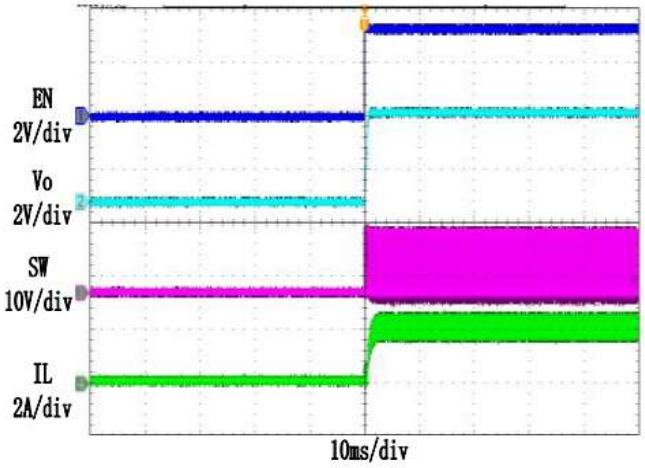
### Steady State Test

**VIN=12V, VOUT=3.3V, IOUT=2A**



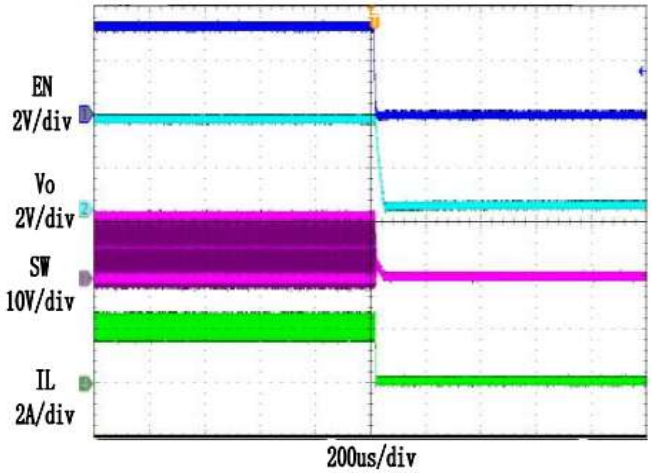

### Startup Through Enable

**VIN=12V, VOUT=3.3V, IOUT=2A(Resistive load)**



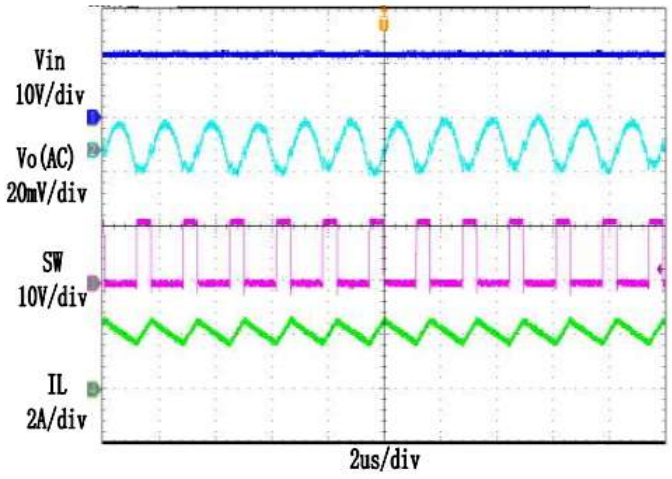

### Shuntdown through Enable

**VIN=12V, VOUT=3.3V, IOUT=2A(Resistive load)**



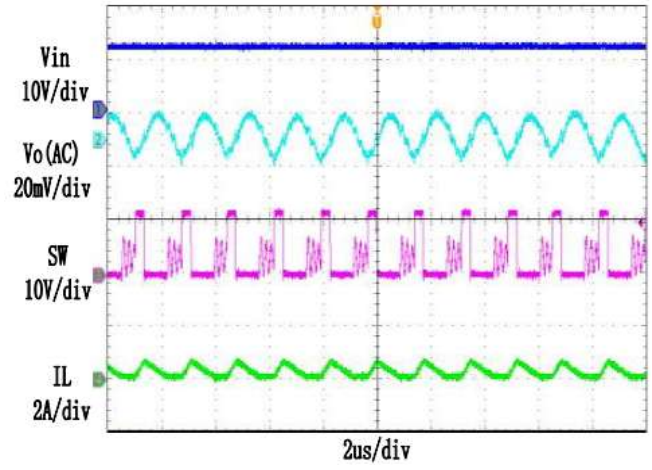

### Heavy Load Operation

**2A LOAD**



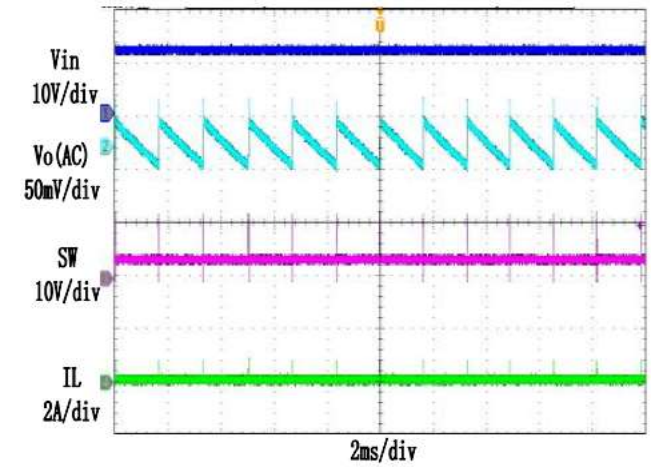

### Medium Load Operation

**0.2A LOAD**




### Light Load Operation

**0A LOAD**



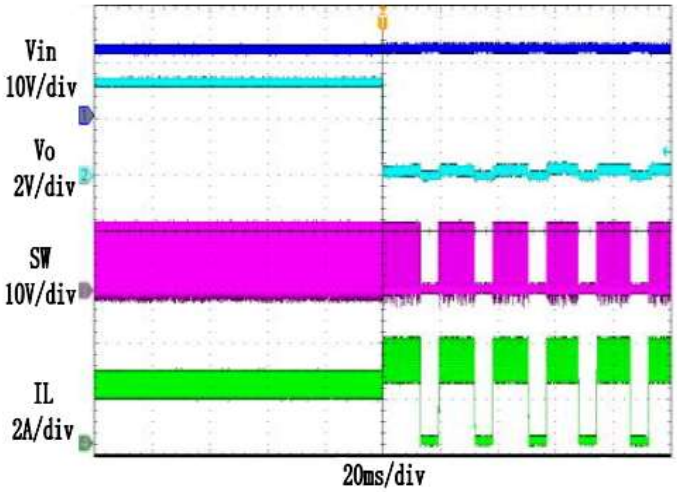
# 600KHz, 28V, 2A Synchronous Step-Down Converter

## Typical Performance Characteristics(Con.)

(Test condition: VIN=12V, VOUT=3.3V, L=4.7uH, COUT=22uF, TA=25'C, unless otherwise noted.)

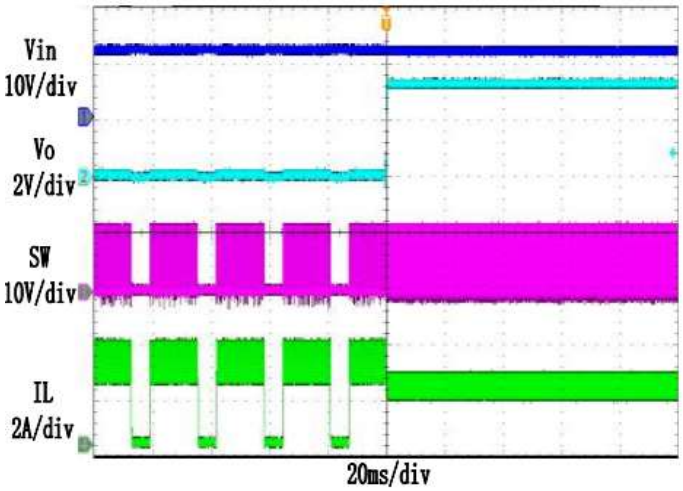
### Short Circuit Protection

VIN=12V, VOUT=3.3V, IOUT=2A-Short



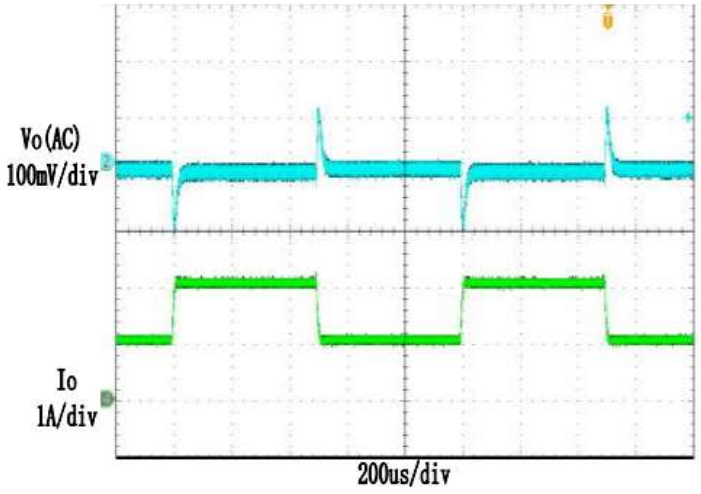

### Short Circuit Recovery

VIN=12V, VOUT=3.3V, IOUT=Short-2A



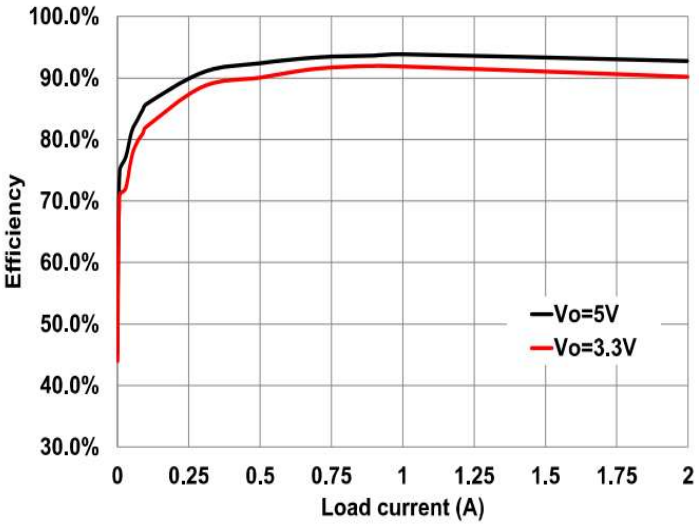

### Load Transient

1A LOAD->2A LOAD->1A LOAD




### Efficiency vs Load Current

Vin=12V, L=4.7uH



# 600KHz, 28V, 2A Synchronous Step-Down Converter

## Functional Block Diagram

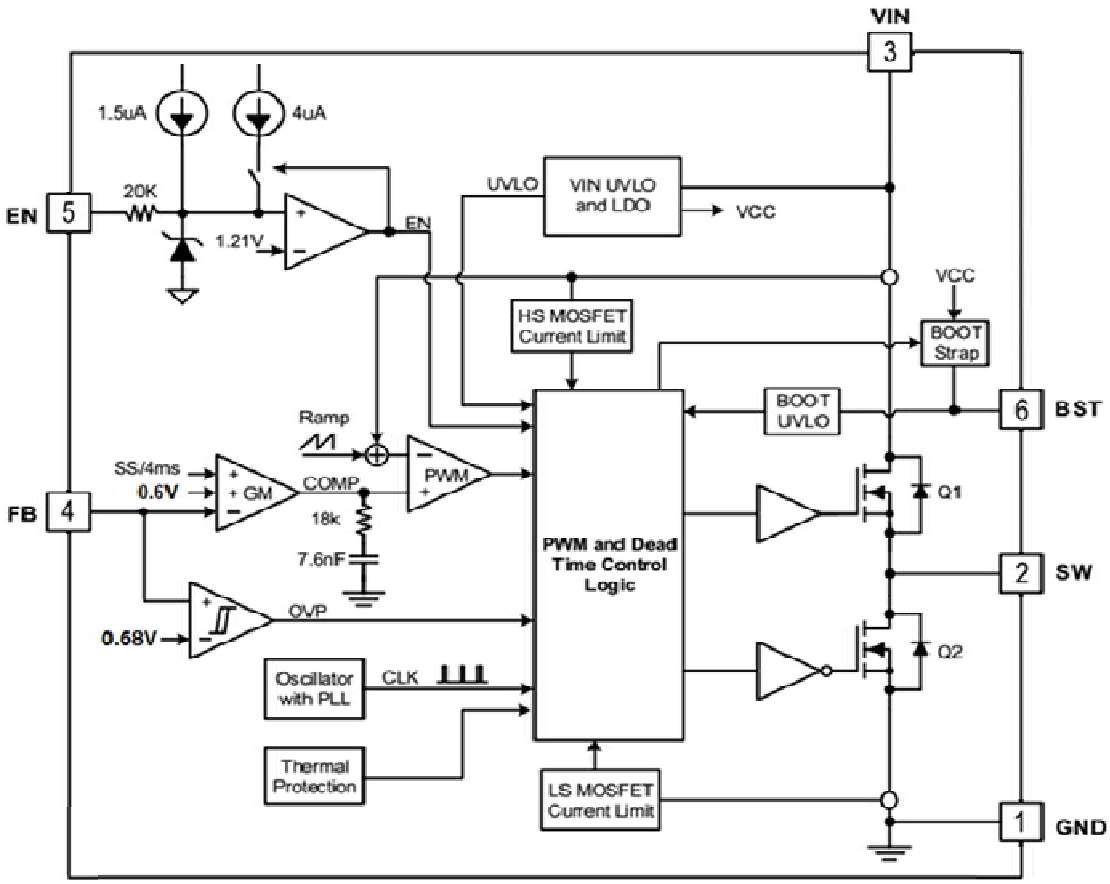
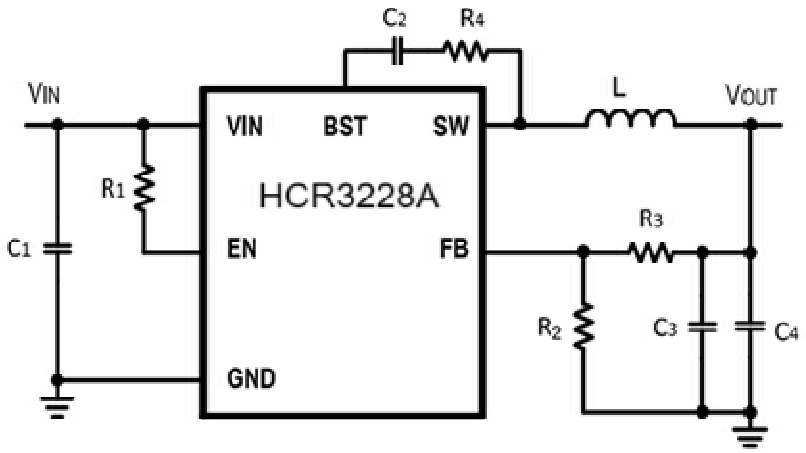



Figure 3. Functional Block Diagram of HCR3228A

## Typical Application Circuit




$$R_3 = R_2 \cdot (\frac{V_{OUT}}{0.6} - 1)$$

**Note: if R2=3KΩ, R3=22KΩ, VFB=0.6V, So the R1 should be selected from 88KΩ to 500KΩ**

**VIN=24V, VOUT=5V/2A**

Figure 4. Typical Application Circuit of HCR3228A

## FUNCTIONAL DESCRIPTION

The HCR3228A is a synchronous, current-mode step-down regulator. It regulates input voltages from 4.5V to 28V down to an output voltage as low as 0.6V, and is capable of supplying up to 2A of load current.

### Current-Mode Control

The HCR3228A utilizes current-mode control to regulate the FB voltage. Voltage at the FB pin is regulated at 0.6V so that by connecting an appropriate resistive divider between VOUT and GND, designed output voltage can be achieved.

### PFM Mode

The HCR3228A operates in PFM mode at light load. In PFM mode, switch frequency decreases when load current drops to boost power efficiency at light load by reducing switch-loss, while switch frequency increases when load current rises, minimizing output voltage ripples.

### Internal Soft-Start

Soft-Start makes output voltage rising smoothly follow an internal SS voltage until SS voltage is higher than the internal reference voltage. It can prevent overshoot of output voltage when startup.

### Power Switch

The N-Channel MOSFET switches are integrated on the HCR3228A to down convert the input voltage to the regulated output voltage. Since the top MOSFET needs a gate voltage greater than the input voltage, a boost capacitor connected between BST and SW pins is required to drive the gate of the top switch. The boost

### Power Switch(con)

capacitor is charged by the internal 3.7V rail when SW is low.

### VIN Under-Voltage Protection

A resistive divider can be connected between VIN and GND, with the central tap connected to EN, so that when VIN drops to the pre-set value, EN drops below 1.1V to trigger input under voltage lockout protection.

### Output Current Run-Away Protection

At start-up,due to the high voltage at input and low vol tage at output, current inertia of the output inductance can be easily built up, resulting in a large start-up output current. A valley current limit is designed in the HCR3228A so that only when output current drops below the valley current limit can the top pow be turned on. By such control mechanism, the output current at start-up is well controlled.

### Over Current Protection and Hiccup

HCR3228A has a cycle-by-cycle current limit. When the inductor current triggers current limit, HCR3228A enters hiccup mode and periodically restart the chip. The HCR3228A will exit hiccup mode while not triggering current limit.

### Thermal Protection

When the temperature of the HCR3228A rises above 150°C, it is forced into thermal shut-down. Only when core temperature drops below 130°C can the regulator becomes active again.

## APPLICATION INFORMATION

### Output Voltage Set

The output voltage is determined by the resistor divider connected at the FB pin, and the voltage ratio is:

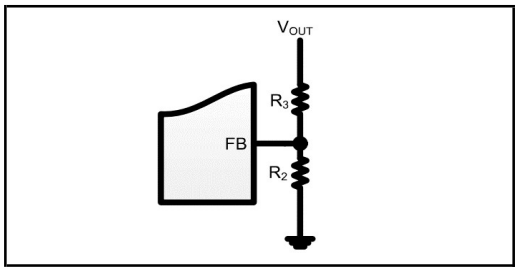
$$V_{FB} = V_{OUT} \cdot \frac{R_2}{R_2 + R_3}$$

where VFB is the feedback voltage and VOUT is the output voltage.

If R2 is determined, and then R3 can be calculated by:

$$R_3 = R_2 \cdot (\frac{V_{OUT}}{0.6} - 1)$$

For better noise immunity, when input voltage is high (e.g. above 18V), the value of low side divider resistor R2 is strongly recommended to be no larger than 3kΩ.




### Input Capacitor

The input capacitor is used to supply the AC input current to the step-down converter and maintaining the DC input voltage. The ripple current through the input capacitor can be calculated by:

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

where ILOAD is the load current, VOUT is the output voltage, VIN is the input voltage.

Thus the input capacitor can be calculated by the following equation when the input ripple voltage is determined.

$$C_1 = \frac{I_{LOAD}}{f_S \cdot \Delta V_{IN}} \cdot \frac{V_{OUT}}{V_{IN}} \cdot (1 - \frac{V_{OUT}}{V_{IN}})$$

### Input Capacitor (Con.)

where C1 is the input capacitance value, fs is the switching frequency, ΔVIN is the input ripple voltage. The input capacitor can be electrolytic, tantalum or ceramic. To minimizing the potential noise, a small X5R or X7R ceramic capacitor, i.e. 0.1μF, should be placed as close to the IC as possible when using electrolytic capacitors.

A 22μF/25V ceramic capacitor is recommended in typical application.

### Output Capacitor

The output capacitor is required to maintain the DC output voltage, and the capacitance value determines the output ripple voltage. The output voltage ripple can be calculated by:

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_S \cdot L} \cdot (1 - \frac{V_{OUT}}{V_{IN}}) \cdot (R_{ESR} + \frac{1}{8 \cdot f_S \cdot C_{OUT}})$$

where COUT (C3//C4) is the output capacitance value and RESR is the equivalent series resistance value of the output capacitor.

The output capacitor can be low ESR electrolytic, tantalum or ceramic, which lower ESR capacitors get lower output ripple voltage. The output capacitors also affect the system stability and transient response, and a 22μF~44μF ceramic capacitor is recommended in typical application.

### Inductor

The inductor is used to supply constant current to the output load, and the value determines the ripple current which affect the efficiency and the output voltage ripple. The ripple current is typically allowed to be 40% of the maximum switch current limit, thus the inductance value can be calculated by:

## APPLICATION INFORMATION (CON.)

### Inductor(con.)

the inductance value can be calculated by:

$$L = \frac{V_{OUT}}{f_S \cdot \Delta I_L} \cdot (1 - \frac{V_{OUT}}{V_{IN}})$$

where VIN is the input voltage, VOUT is the output voltage, fs is the switching frequency, and △IL is the peak-to-peak inductor ripple current.

### External Bootstrap Capacitor

The bootstrap capacitor is required to supply voltage to the top switch driver. A 0.1μF low ESR ceramic capacitor and a 10Ω resistor are recommended to connected to the BST pin and SW pin.

### PCB Layout Note

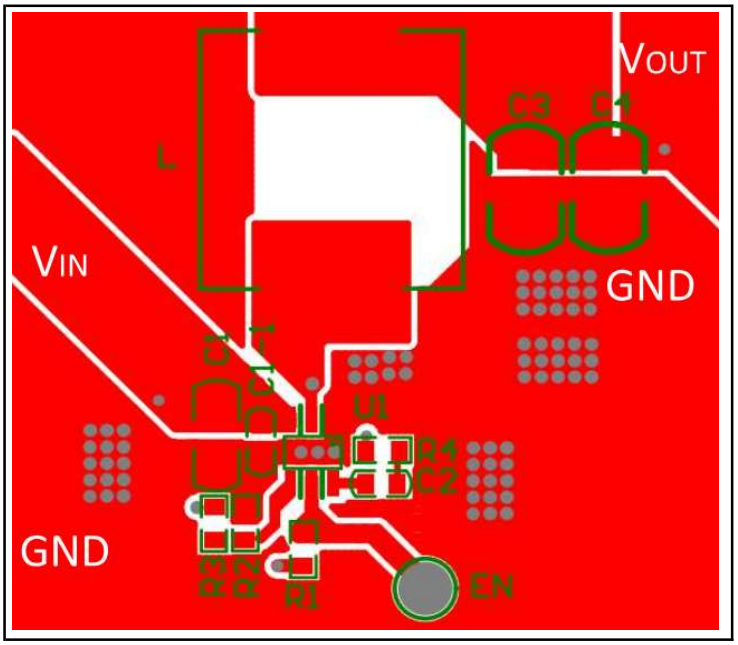
For minimum noise problem and best operating performance, the PCB is preferred to following the guidelines as reference.

1.1 Place the input decoupling capacitor as close to the HCR3228A (VIN pin and GND pin) as possible to eliminate noise at the input pin. The loop area formed by input capacitor and GND must be minimized.

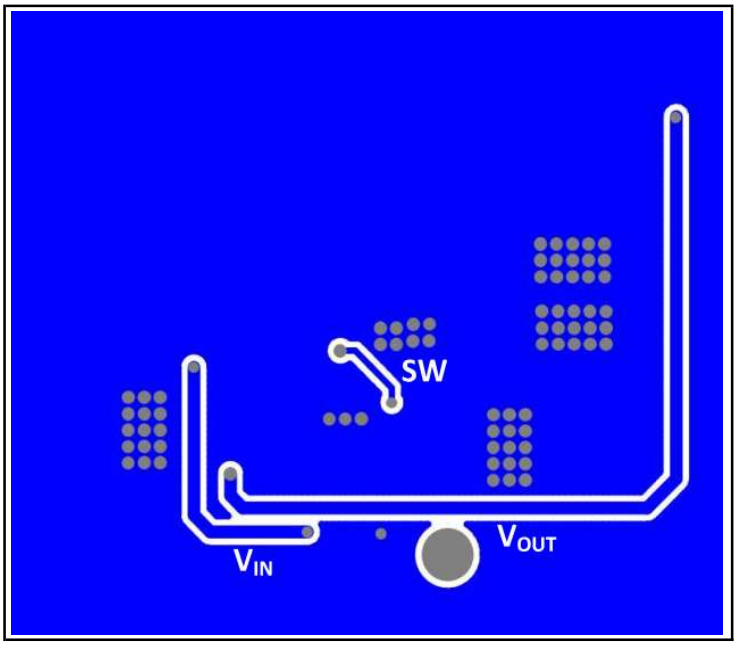
1.2. Put the feedback trace as far away from the inductor and noisy power traces as possible.

1.3. The ground plane on the PCB should be as large as possible for better heat dissipation.

### PCB Layout Note(con.)




Top Layer




Bottom Layer

# REFERENCE DESIGN

**Reference-1: VIN=5V, VOUT=1.2V/2A Schematic Diagram**

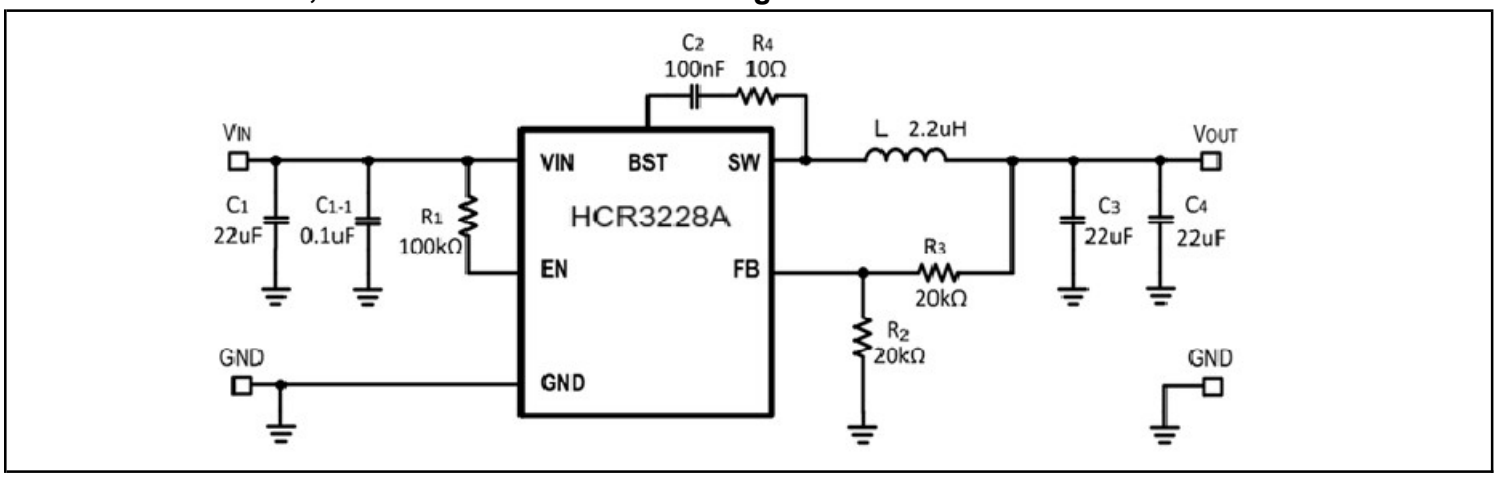



**Figure 5: VIN=5V, VOUT=1.2V/2A Schematic Diagram**

**Reference-2: VIN=12V, VOUT=1.2V/2A Schematic Diagram**

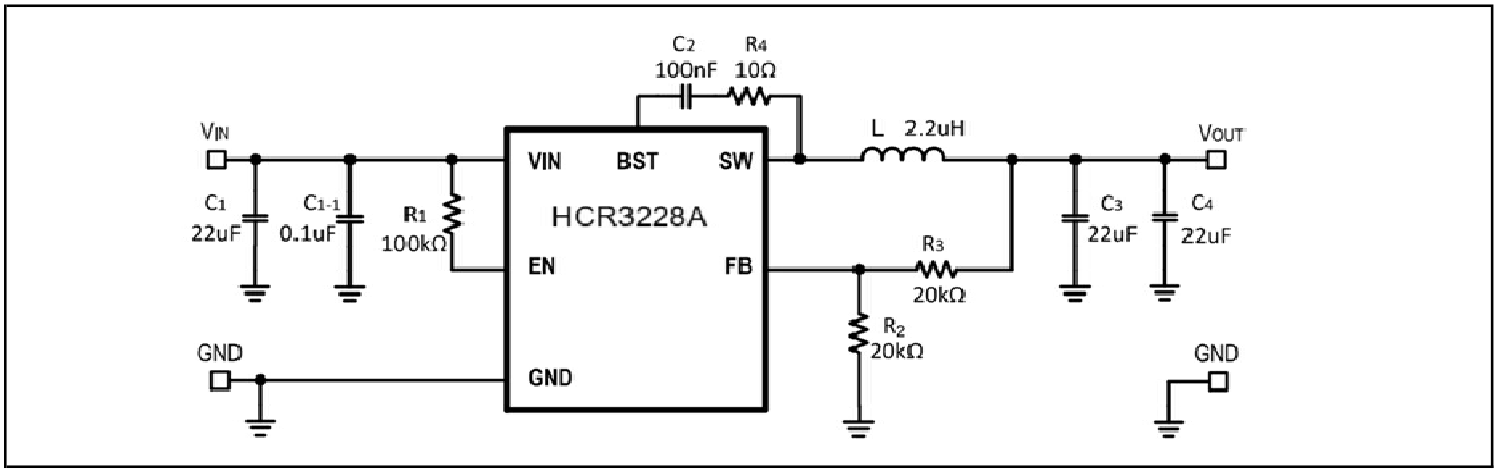



**Figure 6: VIN=12V, VOUT=1.2V/2A Schematic Diagram**

**Reference-3: VIN=12V, VOUT=3.3V/2A Schematic Diagram**

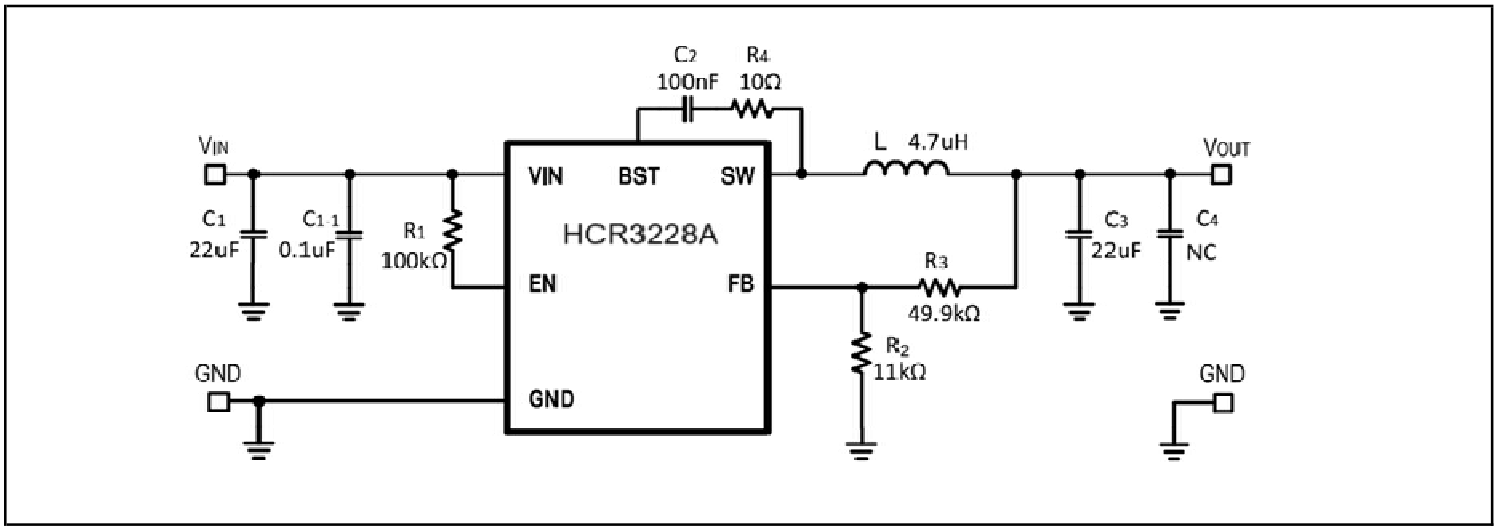



**Figure 7: VIN=12V, VOUT=3.3V/2A Schematic Diagram**

# REFERENCE DESIGN(CON.)

**Reference-4: VIN=24V, VOUT=3.3V/2A Schematic Diagram**

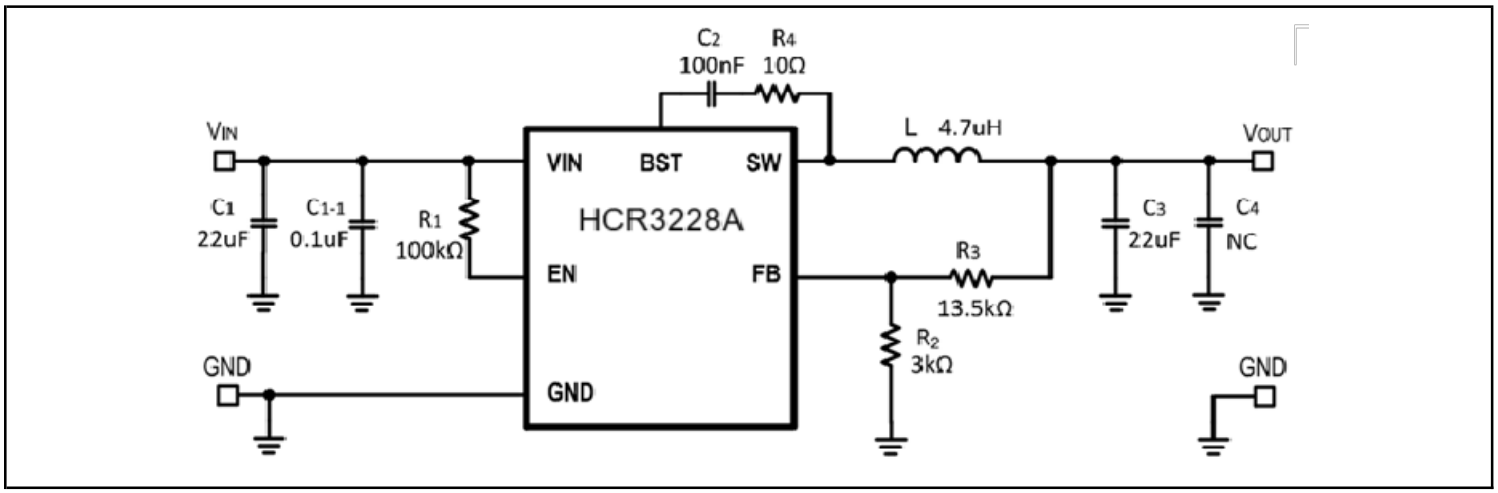



**Figure 8: VIN=24V, VOUT=3.3V/2A Schematic Diagram**

**Reference-5: VIN=12V, VOUT=5V/2A Schematic Diagram**

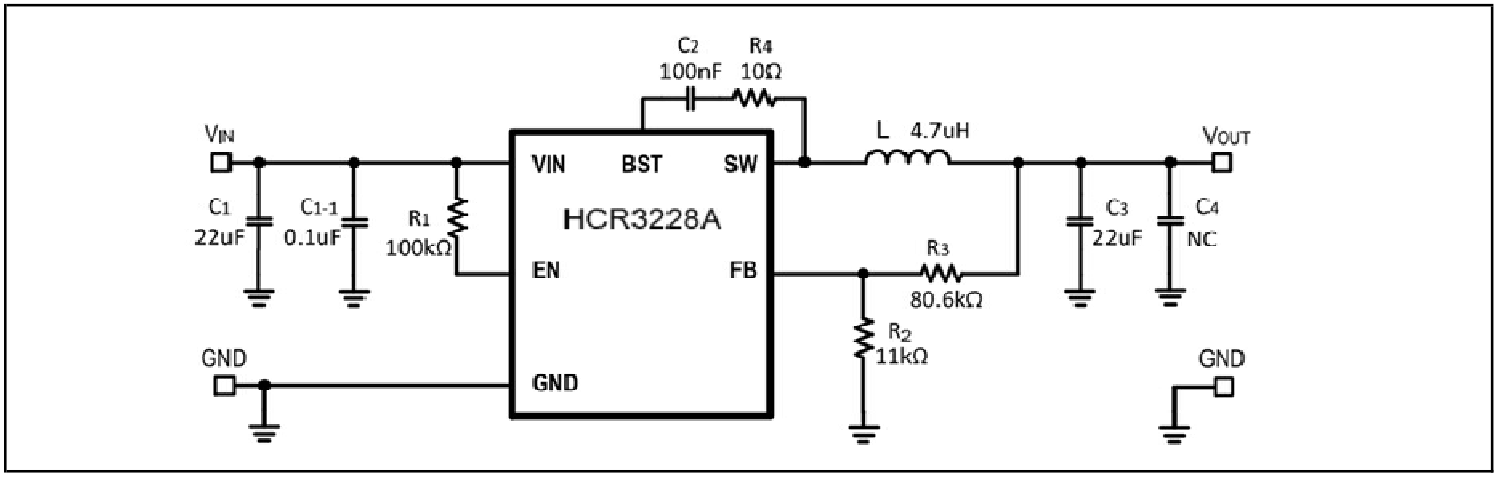



**Figure 9: VIN=12V, VOUT=5V/2A Schematic Diagram**

**Reference-6: VIN=24V, VOUT=5V/2A Schematic Diagram**

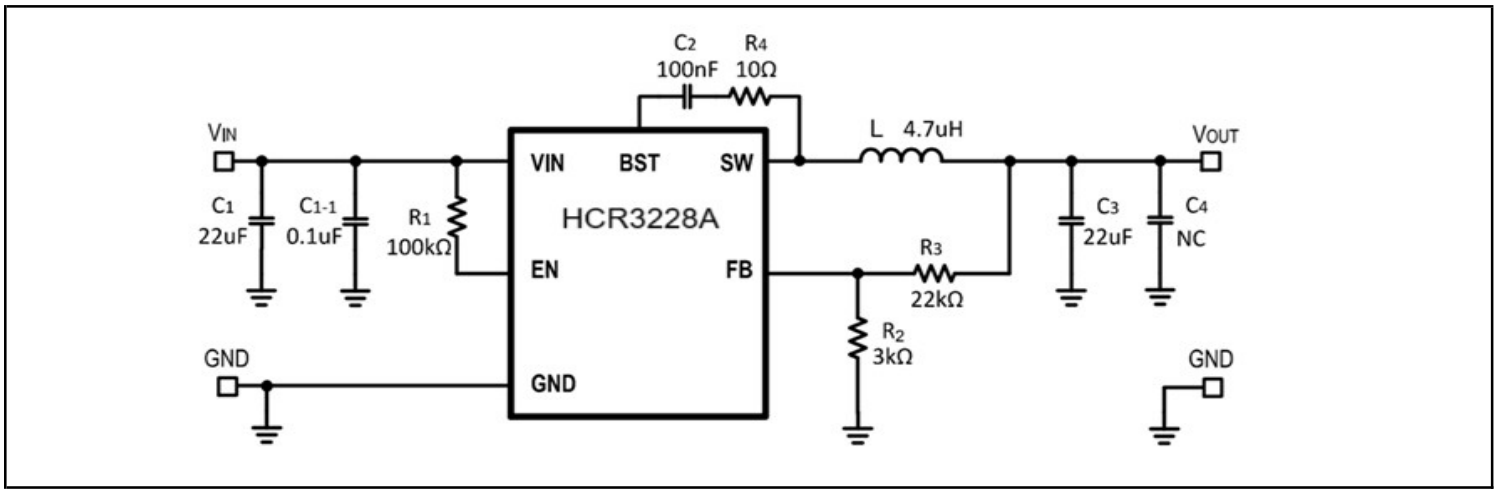
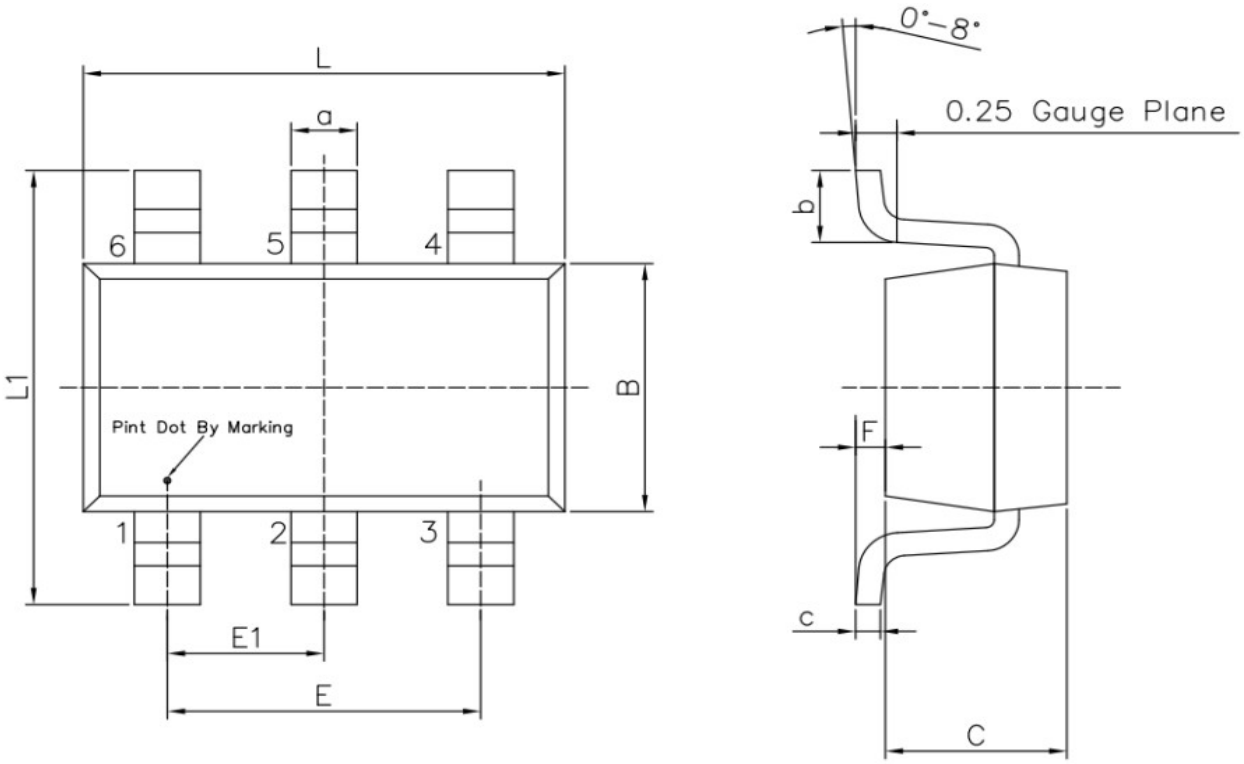



**Figure 10: VIN=24V, VOUT=5V/2A Schematic Diagram**

## Mechanical Dimensions

**M6L PKG: TSOP-6 (SOT23-6L)**

**Unit: mm**



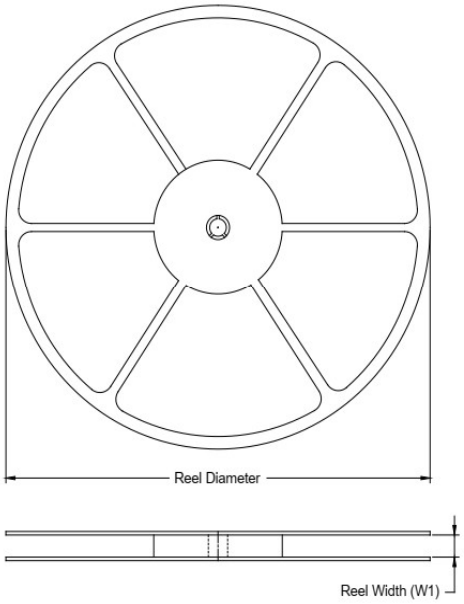

| Symbol | Dimensions In Millimeters | | Symbol | Dimensions In Millimeters | |
|---|---|---|---|---|---|
| | Min | Max | | Min | Max |
| L | 2.82 | 3.02 | E1 | 0.85 | 1.05 |
| B | 1.50 | 1.70 | a | 0.35 | 0.50 |
| C | 0.90 | 1.30 | c | 0.10 | 0.20 |
| L1 | 2.60 | 3.00 | b | 0.35 | 0.55 |
| E | 1.80 | 2.00 | F | 0 | 0.15 |

**Note:**

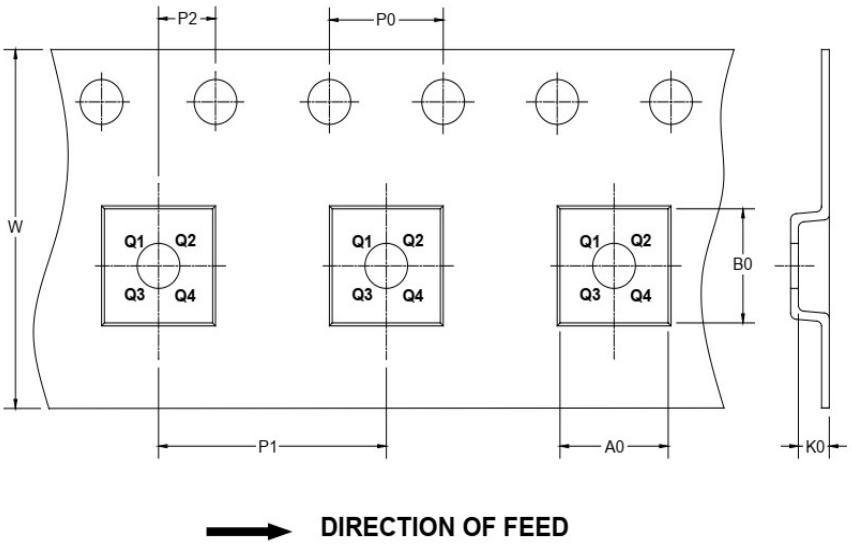
1) All dimensions are in millimeters.
2) Package length does not include mold flash, protrusion or gate burr.
3) Package width does not include inter lead flash or protrusion.
4) Lead popularity (bottom of leads after forming) shall be 0.10 millimeters max.
5) Pin 1 is lower left pin when reading top mark from left to right.

# TAPE AND REEL INFORMATION

## REEL DIMENSIONS




## TAPE DIMENSIONS

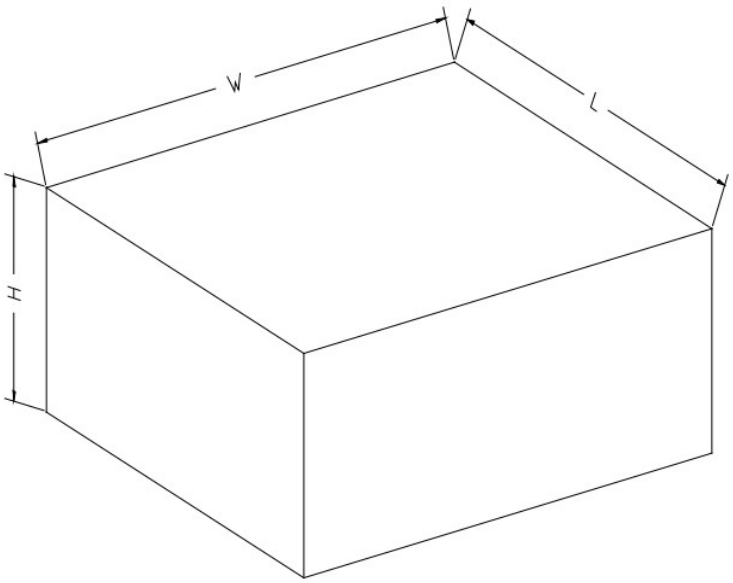



NOTE: The picture is only for reference. Please make the object as the standard.

## KEY PARAMETER LIST OF TAPE AND REEL

| Package Type | Reel Diameter | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P0 (mm) | P1 (mm) | P2 (mm) | W (mm) | Pin1 Quadrant |
|---|---|---|---|---|---|---|---|---|---|---|
| SOT23-6L | 7" | 9.5 | 3.20 | 3.20 | 1.40 | 4.0 | 4.0 | 2.0 | 8.0 | Q3 |

## CARTON BOX DIMENSIONS

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## KEY PARAMETER LIST OF CARTON BOX

| Reel Type | Length (mm) | Width (mm) | Height (mm) | Pizza/Carton |
|---|---|---|---|---|
| 7″ | 442 | 410 | 224 | 18 |