# HM3413D

**3A, 6V, 1MHz, 50uA $I_Q$**
**Synchronous Step-Down Converter**

Parameters Subject to Change Without Notice

## DESCRIPTION

The HM3413D is a current mode monolithic buck switching regulator. Operating with an input range of 2.5V-6V, the HM3413D delivers 3A of continuous output current with integrated P-Channel and N-Channel MOSFETs. The internal synchronous power switches provide high efficiency. At light loads, the regulator operate in low frequency to maintain high efficiency and low output ripples. Current mode control provides tight load transient response and cycle-by-cycle current limit.

The HM3413D guarantees robustness with hiccup output short-circuit protection, FB short-circuit protection, start-up current run-away protection, input under voltage lockout protection, hot-plug in protection, and thermal protection.

The HM3413D provides output power good indication.

The HM3413D is available in 8-pin DFN2X2-8 package, which provides a compact solution with minimal external components.

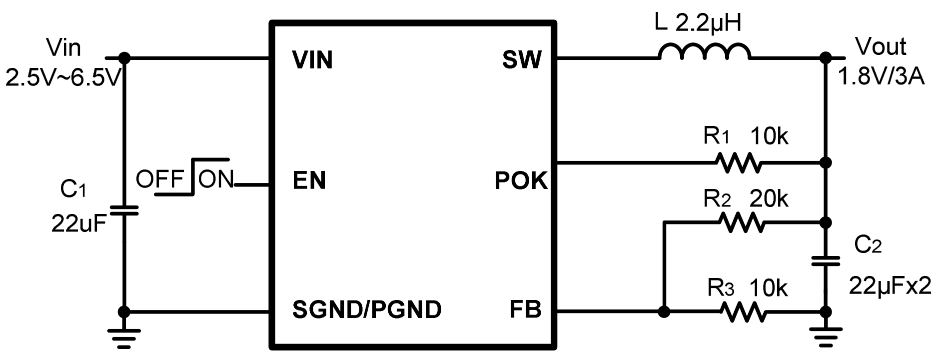
## FEATURES

- 2.5V to 6V operating input range
- Up to 3A output current
- Up to 95% peak efficiency
- High efficiency at light load
- Internal Soft-Start
- 1MHz switching frequency
- Input under voltage lockout
- Short circuit protection
- Thermal protection
- Hot-plug in protection
- Output POK indication
- Available in DFN2X2-8 package

## APPLICATIONS

- 5V or 3.3V Point of Load Conversion
- Set Top Boxes
- Telecom/Networking Systems
- Storage Equipment
- GPU/DDR Power Supply

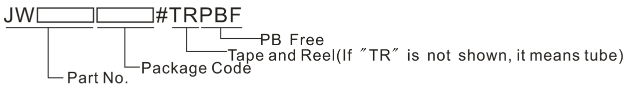
## TYPICAL APPLICATION



## ORDER INFORMATION

| LEAD FREE FINISH | TAPE AND REEL1) | BULK | TRAY | PACKAGE | TOP MARKING2) |
|---|---|---|---|---|---|
| HM3413D | JW5213ADFND#TRPBF | - | - | DFN2X2-8 | JWF6<br>XXXX |

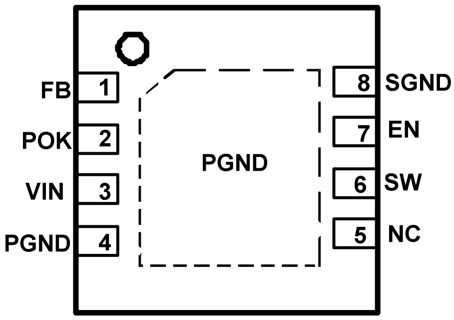
**Notes：**

1) 


2) Line 1 of top marking means Part No., and the line 2 of top marking means Date Code.

## PIN CONFIGURATION

TOP VIEW




DFN2x2-8

## ABSOLUTE MAXIMUM RATING1)

EN, FB, POK Pins ........................................-0.3V to 7.0 V
Vin, SW Pins ........................................-0.3V(-1.7V for 20ns) to 7.0V(7.5V for 70ns)
Junction Temperature.2) 3) ........................................150ºC
Lead Temperature........................................ 260ºC
Storage Temperature........................................ -65ºC to +150ºC
ESD Susceptibility (Human Body Model) ........................................ 2kV

## RECOMMENDED OPERATING CONDITIONS

Input Voltage VIN ........................................2.5V to 6V
Output Voltage Vout........................................ 0.6V to VIN
Operating Junction Temperature........................................ -40ºC to 125ºC

## THERMAL PERFORMANCE4) $\theta_{JA}$ $\theta_{Jc}$

DFN2x2-8........................................120…34ºC/W

**Note：**

1) Exceeding these ratings may damage the device.
2) The HM3413D guarantees robust performance from -40°C to 150°C junction temperature. The junction temperature range specification is assured by design, characterization and correlation with statistical process controls.
3) The HM3413D includes thermal protection that is intended to protect the device in overload conditions. Thermal protection is active when junction temperature exceeds the maximum operating junction temperature. Continuous operation over the specified absolute maximum operating junction temperature may damage the device.
4) Measured on JESD51-7, 4-layer PCB.

## ELECTRICAL CHARACTERISTICS

*VIN=5V, $T_A$=25℃, unless otherwise stated.*

| Item | Symbol | Condition | Min. | Typ. | Max. | Units |
|---|---|---|---|---|---|---|
| $V_{IN}$ Under Voltage Lockout Threshold | $V_{IN\_UVLO}$ | $V_{IN}$ rising | 2.3 | 2.4 | 2.5 | V |
| $V_{IN}$ Under Voltage Lockout Hysteresis | $V_{IN\_UVLO\_HYST}$ | $V_{IN}$ falling | | 200 | | mV |
| $V_{IN}$ Over Voltage Protection Threshold | $V_{IN\_OVP}$ | VIN rising | 6.6 | 6.8 | 7 | V |
| $V_{IN}$ Over Voltage Protection Hysteresis | $V_{IN\_OVP\_HYST}$ | VIN falling | | 400 | | mV |
| Shutdown Current | $I_{SHDN}$ | $V_{EN}$=0V | | 0.1 | 1 | μA |
| Quiescent Current | $I_Q$ | $V_{EN}$=2V, $V_{FB}$=$V_{REF}$*105% | | 50 | | μA |
| Regulated Feedback Voltage | $V_{FB}$ | 2.5V<$V_{IN}$<6V | 0.588 | 0.6 | 0.612 | V |
| PFET On Resistance[5)] | $R_{DSON\_P}$ | VIN=3.6V, $I_{SW}$=200mA | | 110 | | mΩ |
| NFET On Resistance[5)] | $R_{DSON\_N}$ | VIN=3.6V, $I_{SW}$=-200mA | | 90 | | mΩ |
| PFET Leakage Current | $I_{LEAK\_P}$ | $V_{IN}$=5.5V, $V_{EN}$=0V, $V_{SW}$=0V | | | 1 | uA |
| NFET Leakage Current | $I_{LEAK\_N}$ | $V_{IN}$=5.5V, $V_{EN}$=0V, $V_{SW}$=5.5V | | | 1 | uA |
| PFET Current Limit[5)] | $I_{LIM\_TOP}$ | Duty Cycle=100% | 3.5 | 4.8 | | A |
| Switch Frequency | $F_{SW}$ | $I_{OUT}$=1A | 0.8 | 1 | 1.2 | MHz |
| Minimum On Time[5)] | $T_{ON\_MIN}$ | | | 80 | | ns |
| Maximum Duty Cycle | $D_{MAX}$ | | | 95 | | % |
| EN Rising Threshold | $V_{EN\_TH}$ | $V_{EN}$ rising, FB=0.4V | 1.5 | | | V |
| EN Falling Threshold | $V_{EN\_HYST}$ | $V_{EN}$ falling, FB=0.4V | | | 0.4 | V |
| Short Circuit Protection Threshold | $V_{SCP}$ | | | 240 | | mV |
| POK Low Threshold | $V_{POKL}$ | $V_{FB}$ falling | 520 | 540 | 560 | mV |
| POK High Threshold | $V_{POKH}$ | $V_{FB}$ rising | 690 | 720 | 750 | mV |
| Over-voltage Protection Threshold | $V_{OVP}$ | $V_{FB}$ rising | 690 | 720 | 750 | mV |
| Over-voltage Deglitch Time | $T_{OVP}$ | | 20 | 30 | 40 | us |
| SW Discharge Resistance[5)] | $R_{DISC}$ | | | 50 | | Ω |
| Thermal Shutdown Threshold[5)] | $T_{SHDN}$ | | | 150 | | ℃ |
| Temperature Hysteresis[5)] | $T_{HYS}$ | | | 15 | | ºC |

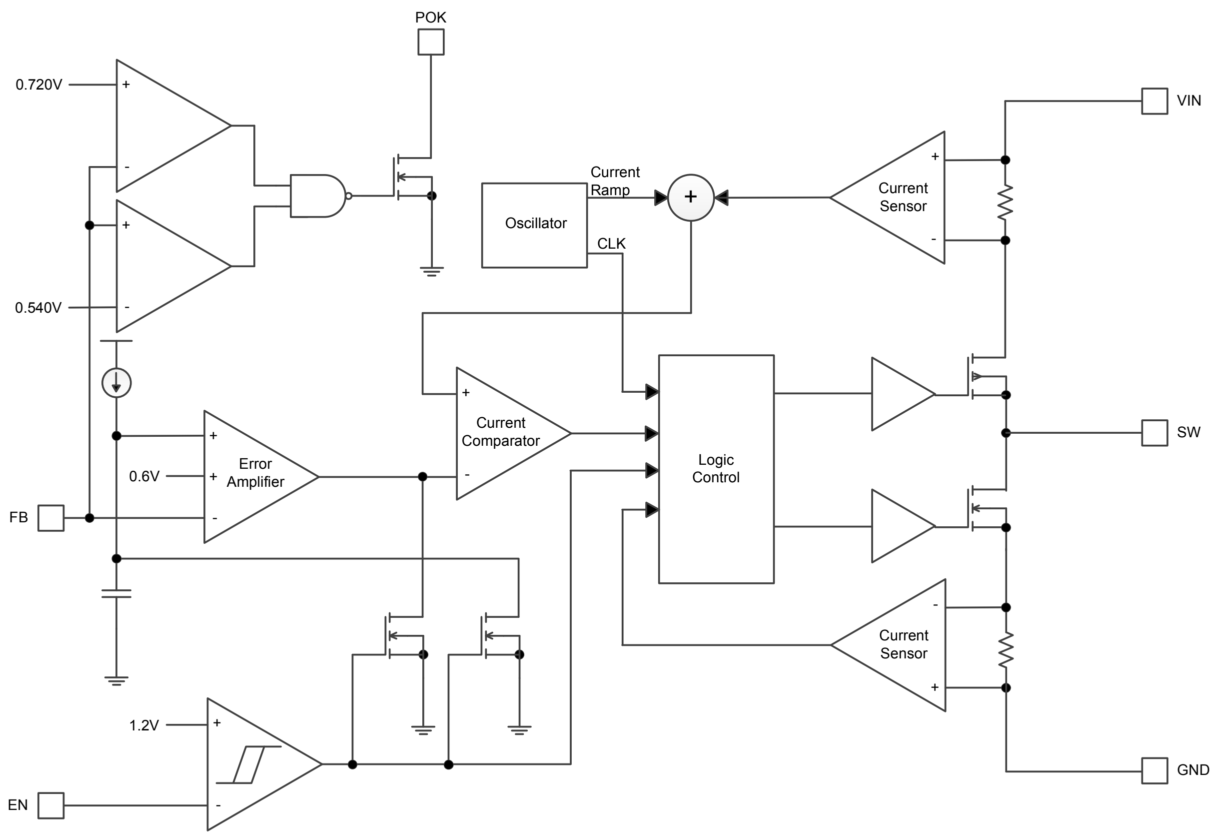
**Note:**

**5)** Guaranteed by design.

## PIN DESCRIPTION

| DFN2X2-8 | Name | Description |
|---|---|---|
| 1 | 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. |
| 2 | POK | Open drain output. Connect a 10KΩ resistor from POK to output. POK is high when $V_{FB}$ is within >90% and <120% of $V_{REF}$. |
| 3 | VIN | Input voltage pin. VIN supplies power to the IC. Connect a 2.5V to 6V supply to VIN and bypass VIN to GND with a suitably large capacitor to eliminate noise on the input to the IC. |
| 4 | PGND | Power ground pin. |
| 5 | NC | No connection. |
| 6 | SW | SW is the switching node that supplies power to the output. Connect the output LC filter from SW to the output load. |
| 7 | EN | Drive EN pin high to turn on the regulator and low to turn off the regulator. |
| 8 | SGND | Signal ground pin. |
| Exposed Pad | PGND | Power ground pin. |

## BLOCK DIAGRAM

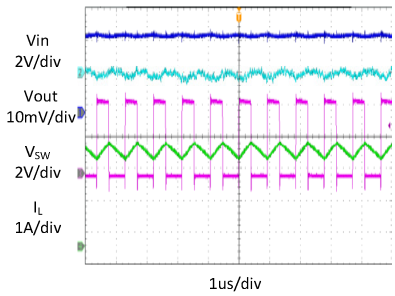


# TYPICAL PERFORMANCE CHARACTERISTICS

Vin = 5V, Vout = 1.8V, L = 2.2μH, Cout = 22μFx2, TA = +25°C, unless otherwise noted

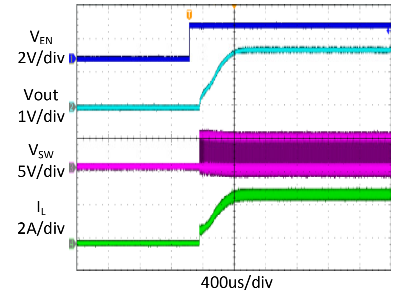
**Steady State Test**

VIN=5V, Vout=1.8V
Iout=3A



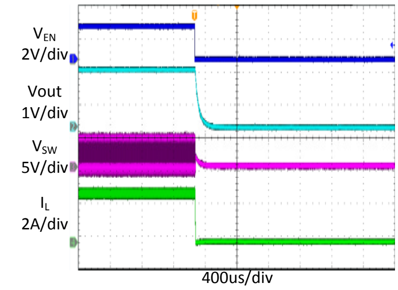

**Startup through Enable**

VIN=5V, Vout=1.8V
Iout=3A(Resistive load)



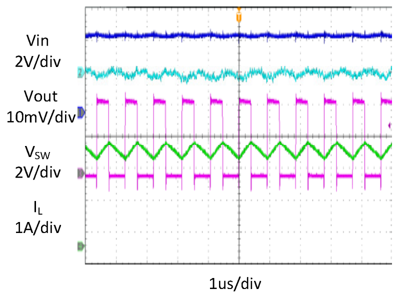

**Shutdown through Enable**

VIN=5V, Vout=1.8V
Iout=3A(Resistive load)



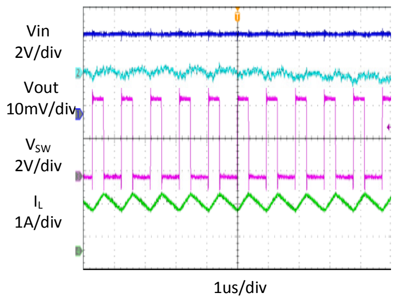

**Heavy Load Operation**

3A LOAD



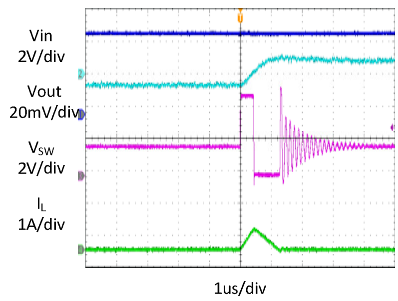

**Medium Load Operation**

1.5A LOAD



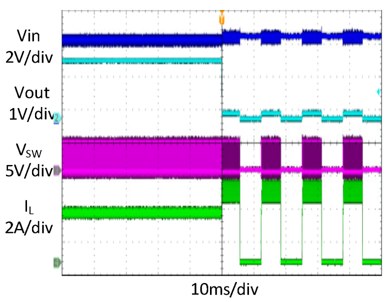

**Light Load Operation**

0 A LOAD



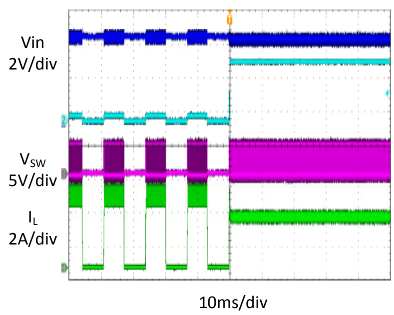

**Short Circuit Protection**

VIN=5V, Vout=1.8V
Iout=3A- Short



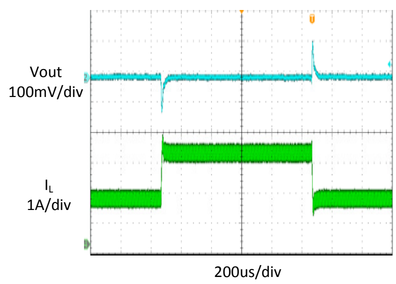

**Short Circuit Protection**

VIN=5V, Vout=1.8V
Iout= Short -3A



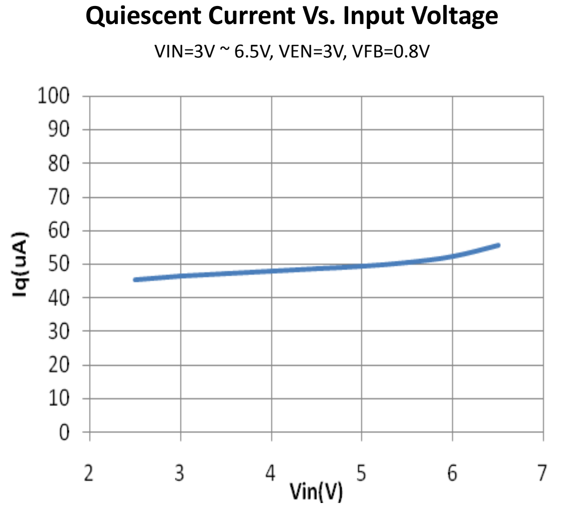

**Load Transient**

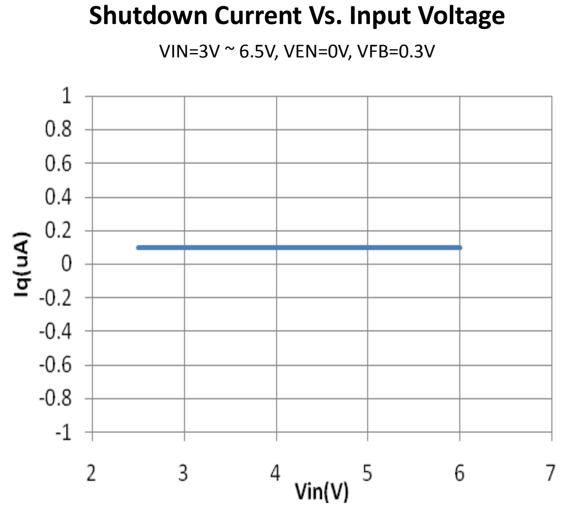
1.5A LOAD → 3A LOAD
→1.5A LOAD

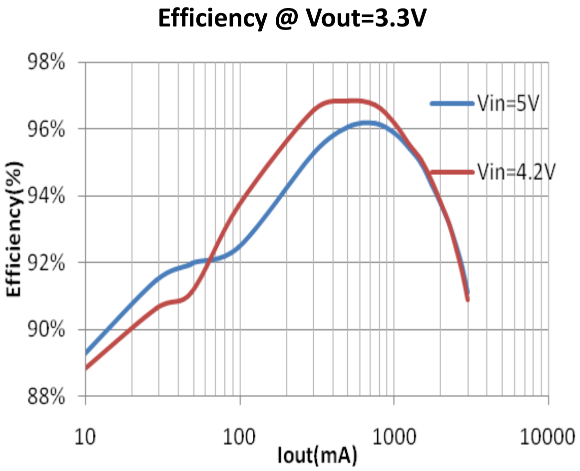


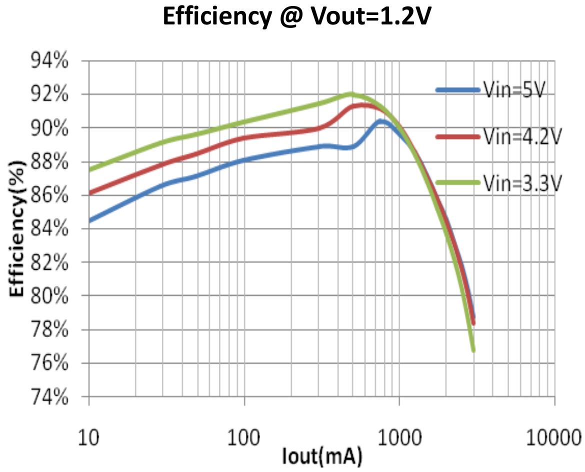
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

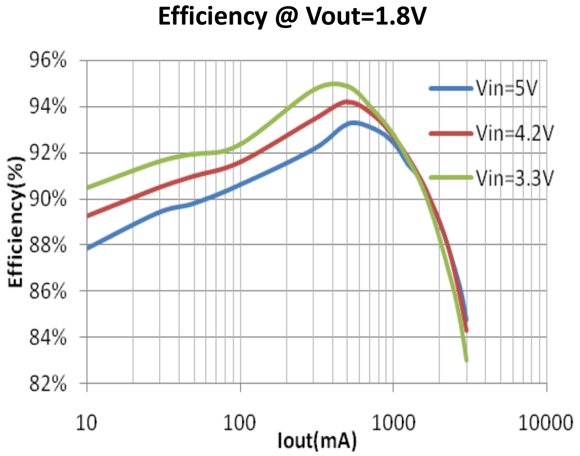
Vin = 5V, Vout = 1.8V, L = 2.2μH, Cout = 44μF, TA = +25°C, unless otherwise noted

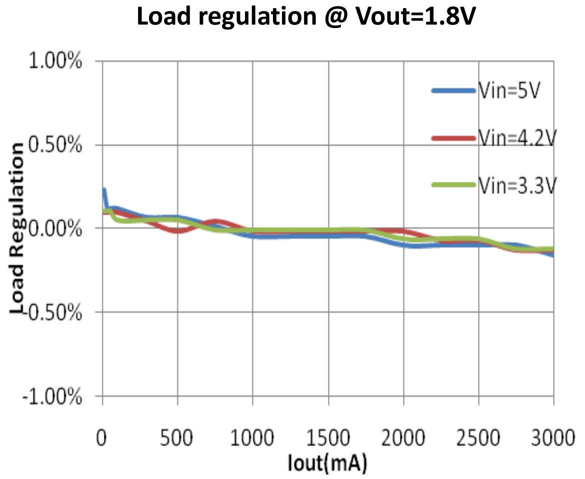


## FUNCTIONAL DESCRIPTION

The HM3413D is a synchronous, current-mode, step-down regulator. It regulates input voltages from 2.5V~6V down to an output voltage as low as 0.6V, and is capable of supplying up to 3A of load current.

### Current-Mode Control

The HM3413D utilizes current-mode control to regulate the output voltage. The output voltage is measured at the FB pin through a resistive voltage divider and the error is amplified by the internal transconductance error amplifier. Output of the internal error amplifier is compared with the switch current measured internally to control the output current limit.

### PFM Mode

The HM3413D operates in PFM mode at light load. In PFM mode, switch frequency is continuously controlled in proportion to the load current, i.e. 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.

### Shut-Down Mode

The HM3413D operates in shut-down mode when voltage at EN pin is driven below 0.4V. In shut-down mode, the entire regulator is off and the supply current consumed by the HM3413D drops below 1uA.

### Power Switches

P-channel and N-channel MOSFET switches are integrated on the HM3413D to down convert the input voltage to the regulated output voltage.

### Hot-Plug In Protection

If the Vin voltage exceeds 6.85V, IC will turn off power switch, entering over-voltage protection. It will remain in this state until Vin voltage is less than 6V.

### Output Current Run-Away Protection

At start-up, due to the high voltage at input and low voltage 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 HM3413D so that only when output current drops below the valley current limit can the bottom power switch be turned off. By such control mechanism, the output current at start-up is well controlled.

### Short Circuit Protection

When output falls below 40% fo the regulation, the switching frequency is reduced to prevent the inductor current from increasing beyond PFET current limit. If short circuit condition holds for more than 1024 cycles, both PFET and NFET are forced off and can be enabled again after 8ms. This procedure is repeated as long as short circuit condition is not removed.

### Thermal Protection

When the temperature of the HM3413D rises above 150°C, it is forced into thermal shut-down.

Only when core temperature drops below 135°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:

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

where $V_{FB}$ is the feedback voltage and $V_{OUT}$ is the output voltage.

Choose $R_3$ around 10Kω, and then $R_2$ can be calculated by:

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

The following table lists the recommended values.

| VOUT(V) | R2(Kω) | R3(Kω) |
|---|---|---|
| 1.2 | 10 | 10 |
| 1.8 | 20 | 10 |
| 2.5 | 31.6 | 10.2 |
| 3.3 | 46.4 | 10.2 |

## 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 $I_{LOAD}$ is the load current, $V_{OUT}$ is the output voltage, $V_{IN}$ is the input voltage.

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

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

where $C_1$ is the input capacitance value, $f_S$ is the switching frequency, $\triangle V_{IN}$ is the input ripple current.

The input capacitor can be electrolytic, tantalum or ceramic. To minimizing the potential noise, a small X5R or X7R ceramic capacitor, i.e. 0.1uF, should be placed as close to the IC as possible when using electrolytic capacitors.

A 10uF 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:

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_S \cdot L} \cdot \left( 1 - \frac{V_{OUT}}{V_{IN}} \right) \cdot \left( R_{ESR} + \frac{1}{8 \cdot f_S \cdot C_2} \right)$$

where $C_2$ is the output capacitance value and $R_{ESR}$ 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 22uF 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 30% of the maximum switch current limit, thus the inductance value can be calculated by:

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

where $V_{IN}$ is the input voltage, $V_{OUT}$ is the output voltage, $f_S$ is the switching frequency, and $\triangle I_L$ is the peak-to-peak inductor ripple current.

## PCB Layout Note

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

1. Place the input decoupling capacitor as close to HM3413D (VIN pin and PGND) as possible to eliminate noise at the input pin. The loop area formed by input capacitor and GND must be minimized.
2. Put the feedback trace as far away from the inductor and noisy power traces as possible.
3. The ground plane on the PCB should be as large as possible for better heat dissipation.

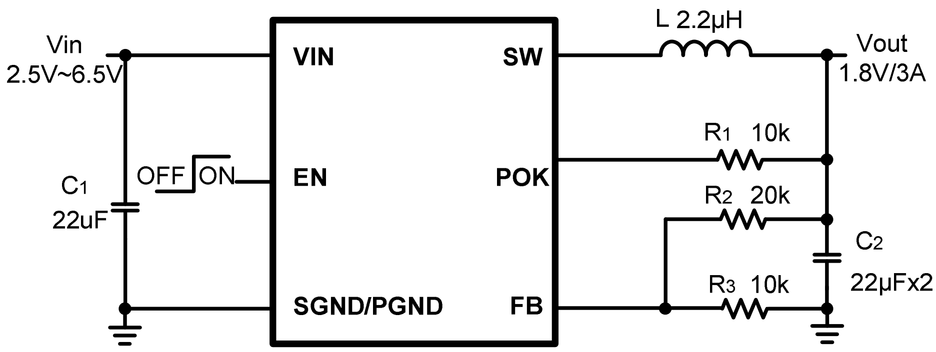
## REFERENCE DESIGN

### Reference 1：

$V_{IN}$: 2.5V ~ 6V

$V_{OUT}$: 1.8V

$I_{OUT}$: 0~3A

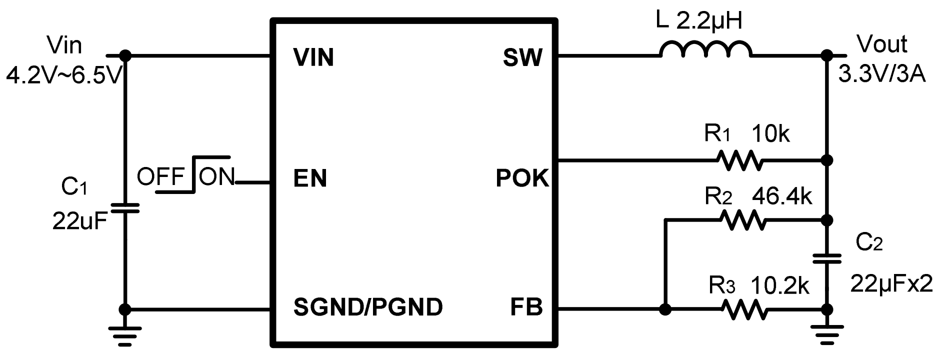



### Reference 2：

$V_{IN}$: 4.2V ~ 6 V

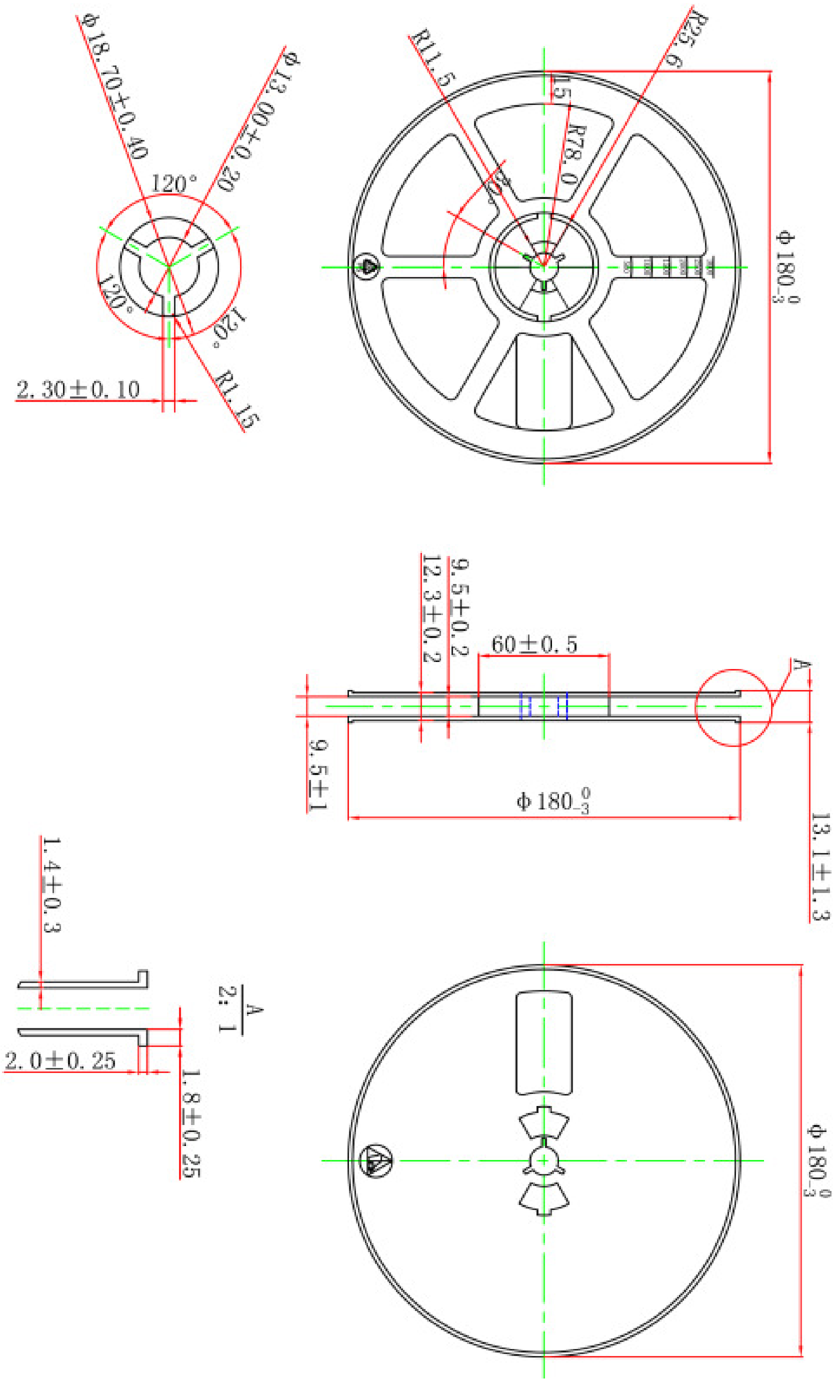
$V_{OUT}$: 3.3V

$I_{OUT}$: 0~3A

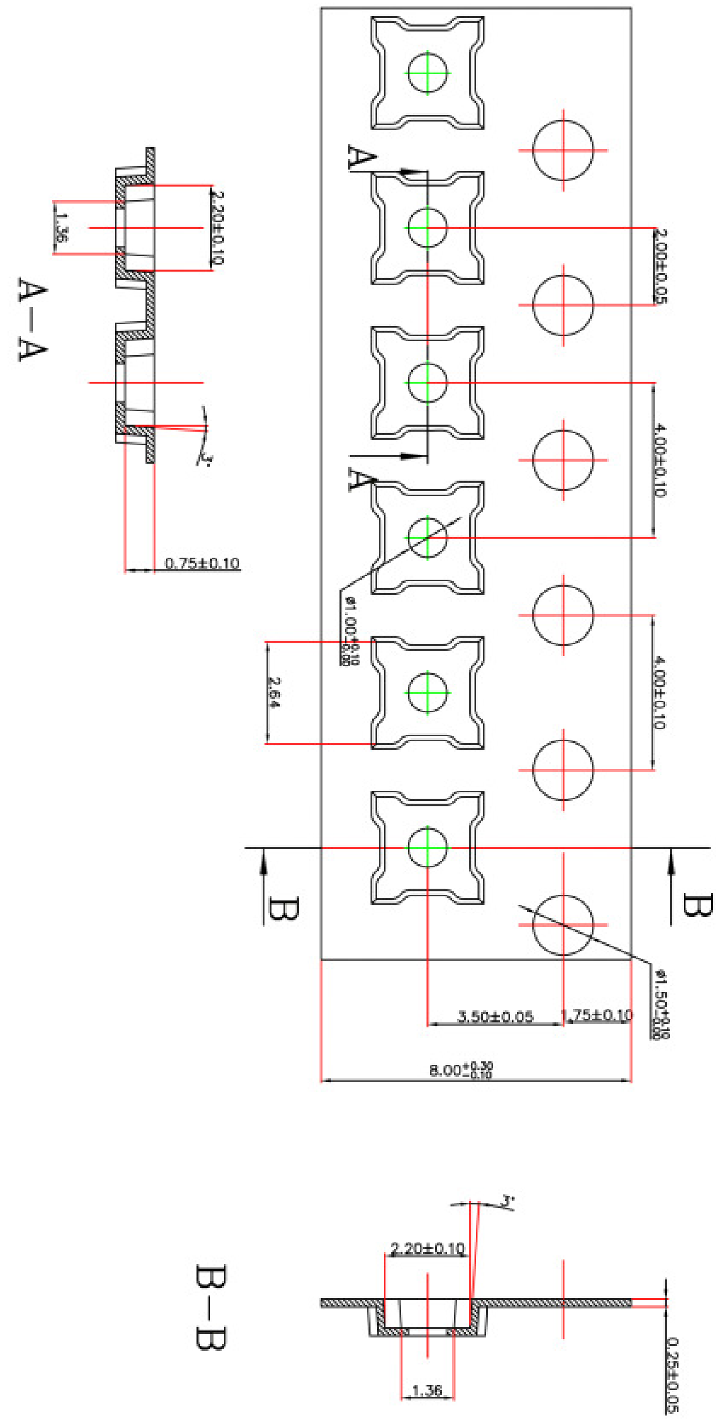


## TAPE AND REEL INFORMATION

| Reel | UNIT: mm |
| --- | --- |



**Carrier Tape** **UNIT: mm**




**Notes:**

1) COVER TAPE WIDTH: 5.50+0.10.
2) COVER TAPE COLOR: TRANSPARENT.
3) 10 SPROCKET HOLE PITCH CUMULATIVE TOLERANCE ±0.20MAX.
4) CAMBER NOT TO EXCEED 1MM IN 100 MM.

## PACKAGE OUTLINE

| DFN2X2-8 | UNIT: mm |
|---|---|