## FEATURES

- Wide Input Voltage from 2.5V to 6V
- Adjustable Output Voltage from 0.8V to VIN
- 3A Continuous Output Current
- Constant on Time (COT) Control
- Forced Continuous Conduction Mode (FCCM) for Light Load
- Stable with low ESR Ceramic Capacitors
- 2.5MHz Switching Frequency
- 100% Duty Cycle Operation for Low Dropout
- Junction Temperature Range from−40℃ to 125℃
- Internal Soft-Start time 2.5ms
- Power Good (PG) Indicator
- Cycle-by-Cycle Output Current Limit Protection
- Hiccup Mode for Short Circuit and Over-Load Protection
- Thermal Shutdown Protection
- LGA-13 (2.5mm×2.5mm×1.24mm) Package
- Pb-Free RoHS Compliant

## APPLICATIONS

- Optical Module
- PoL Power Supply
- Solid-State and Hard Disk Drives

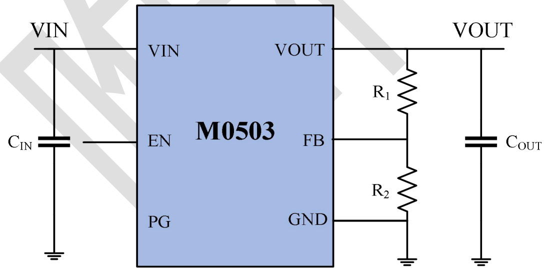
## DESCRIPTION

The M0503 is a 3A step-down switching mode Power SoC (System on Chip) with integrated power MOSFETs and inductor in LGA-13 package. The input voltage is from 2.5V to 6V and the switching frequency is fixed at 2.5MHz.

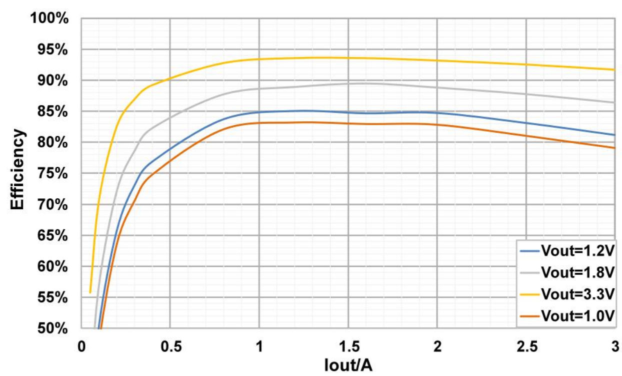
The M0503 provides high efficiency with COT control mode for fast transient response and good loop stability. It works on FCCM which keeps low output ripple and supports 100% duty cycle for low dropout.

The M0503 indicates faults by PG and provides short circuit and over-load hiccup protection and over temperature shutdown protection.

## TYPICAL APPLICATION&EFFICIENCY




(Vin=5V)



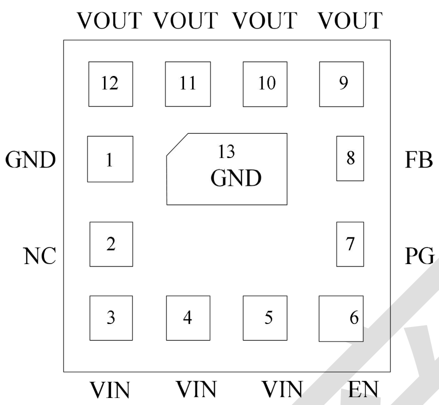
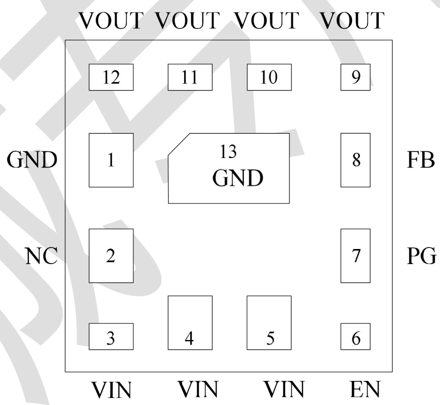
## ORDERING INFORMATION

| PART NUMBER | TOP MARKING | PACKAGE | MOQ | MSL LEVEL |
|---|---|---|---|---|
| M0503DLBGP | M0503<br>YWWLLL | LGA-13<br>(2.5mm×2.5mm×1.24mm) | 3000/<br>Tape & Reel | 3 |
| M0503DLBG [Notes 1)] | M0503<br>YWWLLL[Note 2)] | LGA-13<br>(2.5mm×2.5mm×1.24mm) | 3000/<br>Tape & Reel | 3 |

**NOTES:**

1) M0503DLBG is not recommended for new design.
2) Y: Year, WW: Week, LLL: Lot Number.

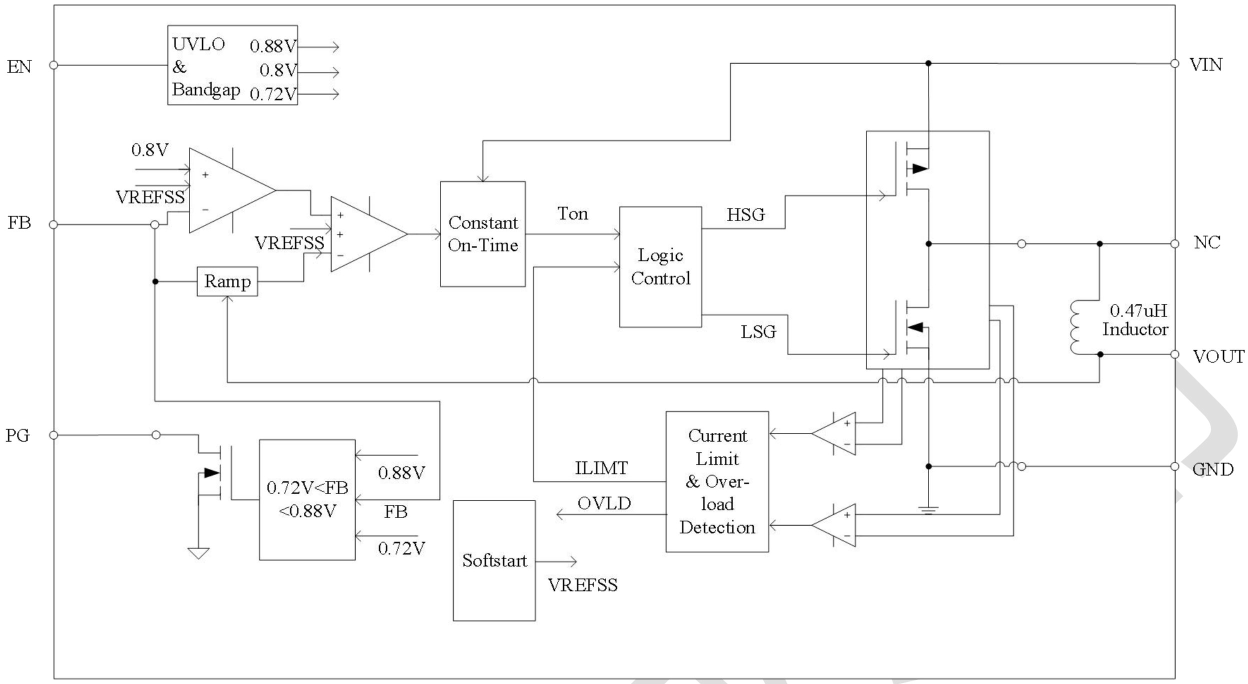
## PACKAGE REFERENCE

| TOP VIEW | |
|---|---|
|   |   |
| LGA-13<br>M0503DLBGP | LGA-13<br>M0503DLBG<br>**(Not recommended for new design)** |

## PIN FUNCTIONS

| PIN # | NAME | DESCRIPTION |
|---|---|---|
| 1,13 | GND | **Power Ground.** |
| 2 | NC | **Not Connected.** |
| 3,4,5 | VIN | **Input Voltage.** VIN supplies power to all the internal control circuitry and the power switch. A decoupling capacitor to ground is recommended in close proximity to VIN. |
| 6 | EN | **Enable Control.** Pull this pin low to shut the chip down. Pull it high to enable the chip. |
| 7 | PG | **Power Good.** The output of PG is an open drain, a pull-up resistor to power source is needed if used. If the chip works normally, PG is pulled high, else, PG is latched low. |
| 8 | FB | **Feedback.** Connect this pin to the center tap of an external resistor divider between the output and GND to set the output voltage. |
| 9,10,11,12 | VOUT | **Output Voltage.** Connect this pin with the load. Output capacitor is recommended to be placed between VOUT and GND. |

## FUNCTIONAL BLOCK DIAGRAM



## ABSOLUTE MAXIMUM RATINGS

| | SYMBOL | MIN | MAX | UNIT |
|---|---|---|---|---|
| Voltage at Pins | $V_{IN}$ | −0.3 | 6.5 | V |
| Voltage at Other Pins | | −0.3 | 6 | V |
| Junction Temperature Range | $T_J$ | −40 | 125 | ℃ |
| Storage Temperature Range | $T_S$ | −55 | 150 | ℃ |
| Solder Reflow Body Temperature Range | | | 245 | ℃ |
| Power Dissipation ($T_A$=+25℃) | $P_D$ Notes 1) | | 1.87 | W |

## RECOMMENDED OPERATING CONDITIONS

| | SYMBOL | MIN | MAX | UNIT |
|---|---|---|---|---|
| Input Voltage Range | $V_{IN}$ | 2.5 | 5.5 | V |
| Output Voltage Range | $V_{OUT}$ | 0.8 | $V_{IN}$ | V |
| Output Current | $I_{OUT}$ | | 3 | A |
| Junction Temperature Range | $T_J$ | −40 | 125 | ℃ |

## THERMAL RESISTANCE

| | SYMBOL | MIN | MAX | UNIT |
|---|---|---|---|---|
| Junction to Ambient | $\theta_{JA}$ Notes 2) | | 53.5 | ℃/W |
| Junction to Case | $\theta_{JC}$ Notes 2) | | 2 | ℃/W |

**NOTES:**

1) The maximum allowable continuous power dissipation at any ambient temperature ($T_A$) is calculated by $P_D(max)=(T_J(max)-T_A)/\theta_{JA}$. Exceeding the maximum allowable power dissipation will cause excessive die temperature, and the power module will go into thermal shutdown.
2) Measured on EVB, 2-layer PCB 1oZ.

# ELECTRICAL CHARACTERISTICS

$V_{IN}$=5V, $T_A$=25°C, unless otherwise noted. Typical values are at $V_{EN}$=3.6V and $V_{OUT}$=1.2V.

| PARAMETERS | SYMBOL | CONDITION | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| Input Voltage | $V_{IN}$ | | 2.5 | | 6.0 | V |
| Input under Voltage Lockout Threshold | $V_{UVLO}$ | $V_{IN}$ Increasing | | 2.4 | | V |
| Input under Voltage Lockout Hysteresis | | | | 270 | | mV |
| Input over Voltage Lockout Threshold | $V_{OVLO}$ | $V_{IN}$ Increasing | | 6.6 | | V |
| Input over Voltage Lockout Hysteresis | | | | 410 | | mV |
| Shutdown Current | $I_{SD}$ | $V_{EN}$=0, $V_{IN}$=5.5V | | 0.1 | 5 | μA |
| Quiescent Current (No Switching) | $I_Q$ | $V_{FB}$=0.63V | | 460 | | μA |
| EN On Threshold | | $V_{EN}$ Increasing | | 1.21 | | V |
| EN Off Threshold | | $V_{EN}$ Decreasing | | 1.1 | | V |
| EN Internal Pull-Down Resistor | | | | 1000 | | kΩ |
| Feedback Voltage | $V_{FB\_REF}$ | | 792 | 800 | 808 | mV |
| HS Switch Current Limit | | | | 5 | | A |
| Switching Frequency | $F_{SW}$ | | | 2.5 | | MHz |
| Soft-Start Time | $T_{SS}$ | | | 2.5 | | ms |
| PG Output Low Voltage | | $V_{FB}$=0.5V, sink 1mA | | 0.2 | 0.3 | V |
| PG Under Voltage Rise Threshold | | $V_{FB}$ in respect to the regulation | −12 | −10 | −8 | % |
| PG Under Voltage Fall Threshold | | $V_{FB}$ in respect to the regulation | | −13 | | % |
| PG Delay | $T_{PG\_DELAY}$ | | | 30 | | μs |
| Thermal Shutdown | | | | 160 | | ℃ |
| Thermal Shutdown Hysteresis | | | | 30 | | ℃ |

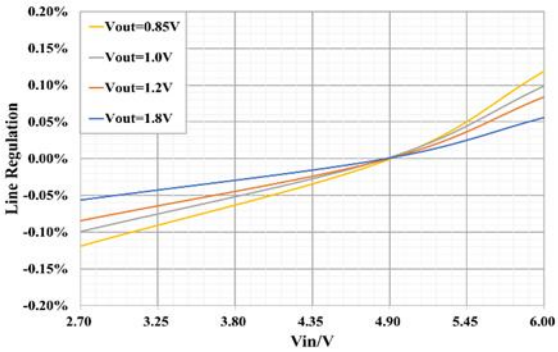
## TYPICAL PERFORMANCE CHARACTERISTICS

$V_{IN}$=5V, $T_A$=25°C, $F_{SW}$=2.5MHz, $V_{OUT}$=1.2V, unless otherwise noted.

**Line Regulation**

$V_{OUT}$=1.2V, $I_{OUT}$=3A,

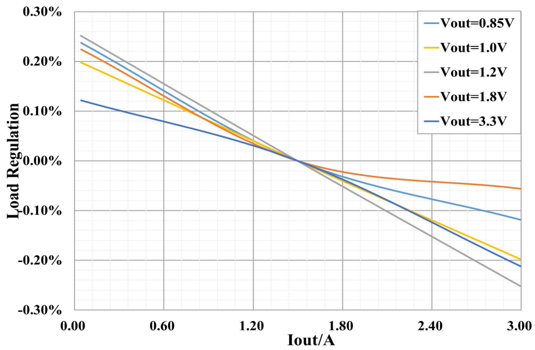
$V_{IN}$=2.5~6V




**Load Regulation**

$V_{IN}$=5V, $V_{OUT}$=1.2V,

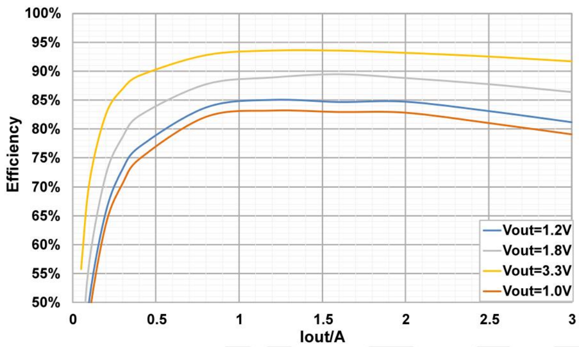
$I_{OUT}$=0~3A




**Efficiency**

$V_{IN}$=5V, $V_{OUT}$=1.0V/1.2V/1.8V/3.3V,

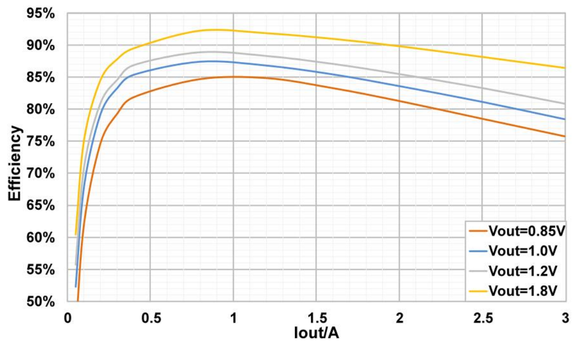
$I_{OUT}$=0~3A




**Efficiency**

$V_{IN}$=3.3V,$V_{OUT}$=0.85V/1.0V/1.2V/1.8V,

$I_{OUT}$=0~3A

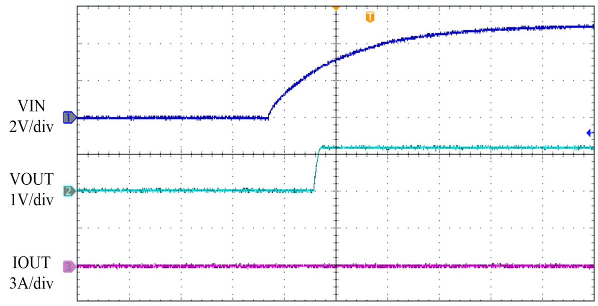


## TYPICAL PERFORMANCE CHARACTERISTICS (continued)

$V_{IN}$=5V, $T_A$=25°C, $F_{SW}$=2.5MHz, $V_{OUT}$=1.2V, unless otherwise noted.

**VIN Start-up**

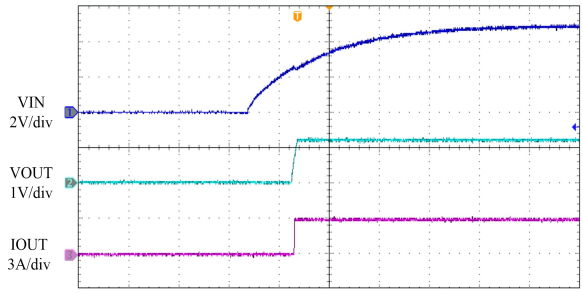
$I_{OUT}$=0A




20ms/div

**VIN Start-up**

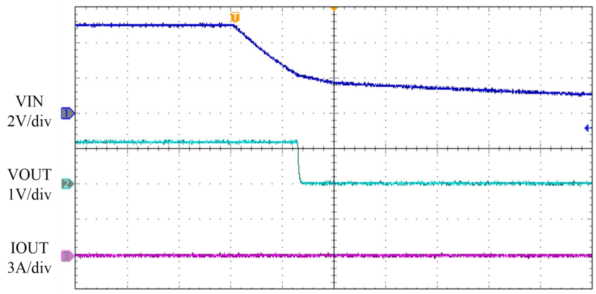
$I_{OUT}$=3A




20ms/div

**VIN Shutdown**

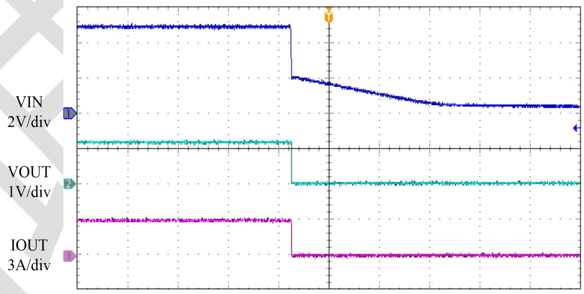
$I_{OUT}$=0A




20ms/div

**VIN Shutdown**

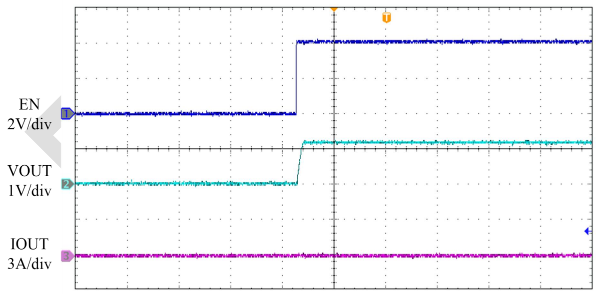
$I_{OUT}$=3A




20ms/div

**EN Start-up**

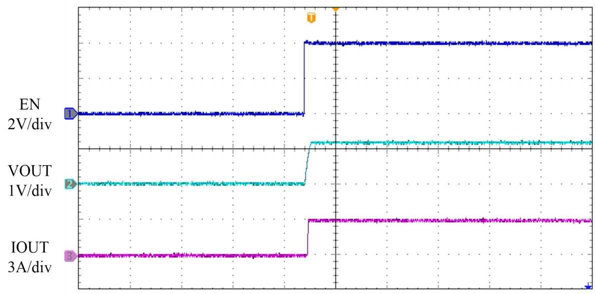
$I_{OUT}$=0A




20ms/div

**EN Start-up**

$I_{OUT}$=3A



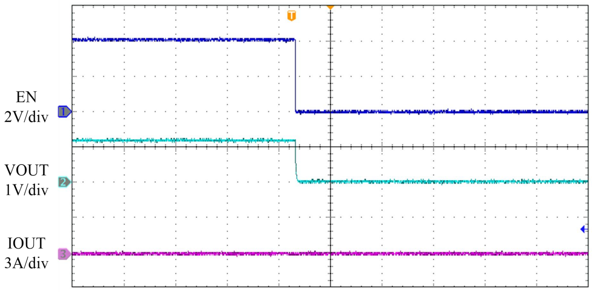

20ms/div

## TYPICAL PERFORMANCE CHARACTERISTICS (continued)

$V_{IN}$=5V, $T_A$=25°C, $F_{SW}$=2.5MHz, $V_{OUT}$=1.2V, unless otherwise noted.

**EN Shutdown**

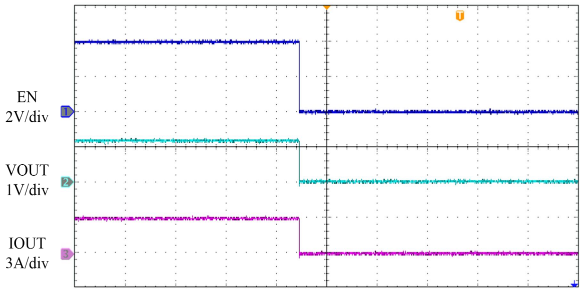
$I_{OUT}$=0A




20ms/div

**EN Shutdown**

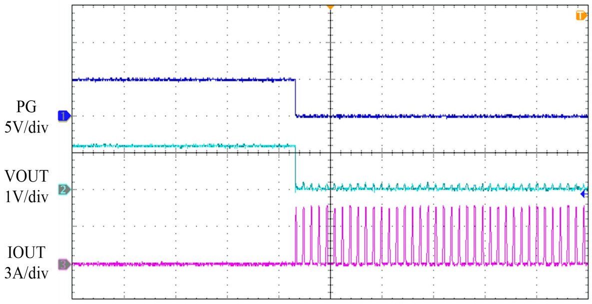
$I_{OUT}$=3A




20ms/div

**SCP Entry**

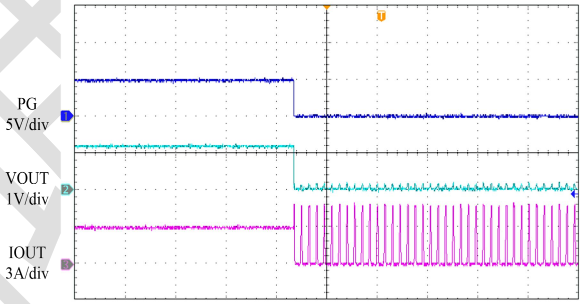
$I_{OUT}$=0A




10ms/div

**SCP Entry**

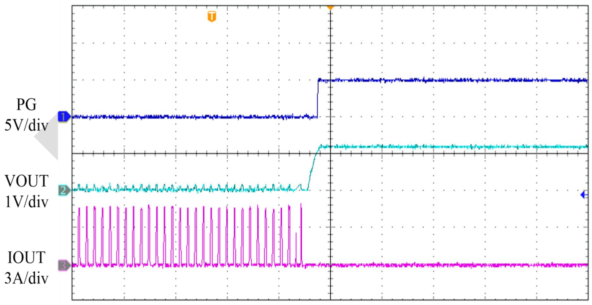
$I_{OUT}$=3A




10ms/div

**SCP Recovery**

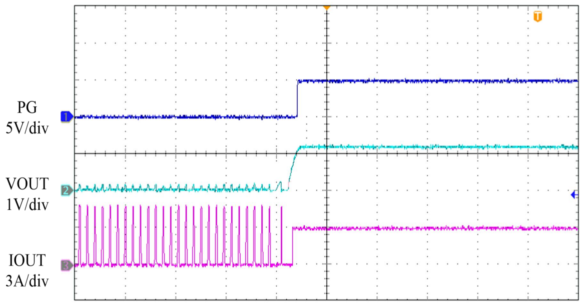
$I_{OUT}$=0A




10ms/div

**SCP Recovery**

$I_{OUT}$=3A



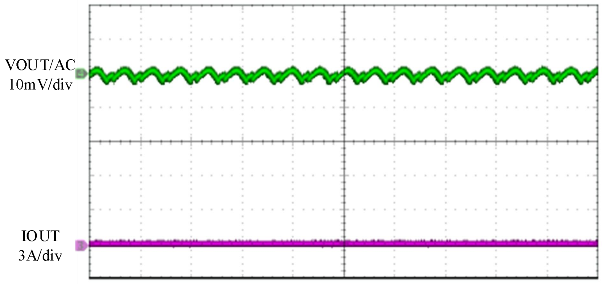

10ms/div

## TYPICAL PERFORMANCE CHARACTERISTICS (continued)

$V_{IN}$=5V, $T_A$=25°C, $F_{SW}$=2.5MHz, $V_{OUT}$=1.2V, unless otherwise noted.

**VOUT Ripple**

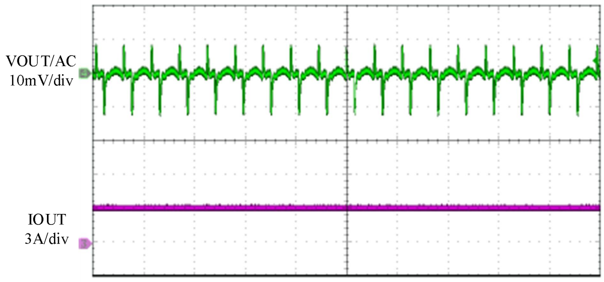
$I_{OUT}$=0A




800ns/div

**VOUT Ripple**

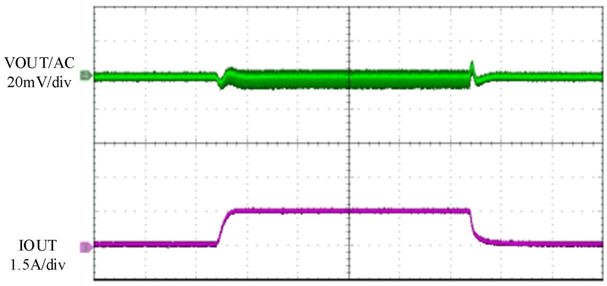
$I_{OUT}$=3A




800ns/div

**Load Transient**

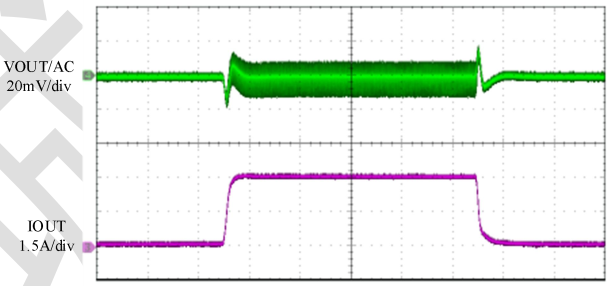
$I_{OUT}$=0A to 1.5A, 1A/µs




100µs/div

**Load Transient**

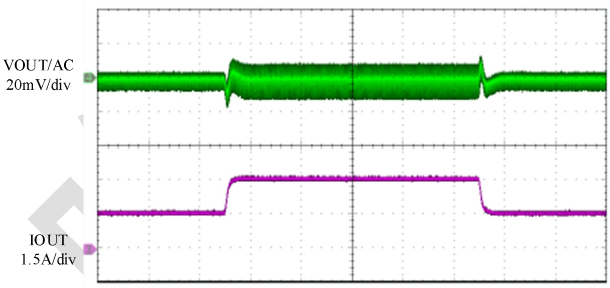
$I_{OUT}$=0A to 3A, 1A/µs




100µs/div

**Load Transient**

$I_{OUT}$=1.5A to 3A, 1A/µs




100µs/div

## OPERATION

The M0503 is a 3A synchronous step-down switching mode Power SoC with integrated high-side and low-side power MOSFETs and inductor in LGA-13 package. Only FB resistors, input and output capacitors are needed to complete the design over 2.5V to 6V input voltage range. The M0503 supports output voltage of 0.8V to 6V with the fixed switching frequency of 2.5MHz.

M0503 works on COT control mode that offers excellent transient response over the wide range of input voltage. M0503 operates in Forced Continuous Conduction Mode (FCCM) which keeps low output ripple. M0503 can work on 100% duty cycle when the dropout between input and output is low. The soft start time of M0503 is 2.5ms internally.

Fully integrated protection features include OCP, UVP, OTP and all these faults can be indicated by PG. The protection function details are shown below.

### OVER CURRENT PROTECTION (OCP)

M0503 has a typical 5A cycle-by-cycle High-Side current limit protection to prevent inductor current from running away. When the High-Side switch reaches the current limit, M0503 will enter hiccup mode. It will stop switching for a pre-determined period of time and automatically start up again. It always starts up with soft-start to limit inrush current and avoid output overshoot.

### OVER TEMPERATURE PROTECTION (OTP)

M0503 will stop switching when the junction temperature exceeds 160 °C. The device will power up again when the junction temperature drops below 130°C.

# USER GUIDE

## Output Voltage

The output voltage is set by the external feedback resistor divider as the typical application circuit on Page 1. A large bottom feedback resistor $R_2$ can make FB noise-sensitive. For any chosen $R_2$, the top feedback resistor $R_1$ can be calculated as:

$$R_1=R_2\cdot\left(\frac{V_{OUT}}{V_{FB}}-1\right)$$

Table 1 lists the recommended feedback resistor values for common output voltages.

**Table 1: FB Resistor Values for Common Output Voltages.**

| $V_{OUT}$(V) | $R_1$(kΩ) | $R_2$(kΩ) |
|---|---|---|
| 3.3 | 100 | 31.6 |
| 1.8 | 37.4 | 30 |
| 1.2 | 15 | 30 |
| 1.0 | 7.5 | 30 |

## Input Capacitor Selection

The input current of the step-down converter is discontinuous with sharp edges, therefore, placing input filter capacitors is necessary. For better performance, low ESR ceramic capacitor with X5R or X7R dielectrics are highly recommended because of their lowest temperature variations. The RMS current of the input capacitor is calculated:

$$I_{CIN\_RMS}=I_{OUT}\sqrt{D(1-D)}$$

in which D is the Duty Cycle and when the current is continuous, $D=V_{OUT}/V_{IN}$; $I_{OUT}$ is the output load current. As the equation above, when D is 0.5, the highest RMS current is approximately:

$$I_{CIN\_RMS}=\frac{1}{2}\times I_{OUT}$$

So, it is recommended to choose the capacitors with the RMS current rating higher than 1/2 $I_{OUT}$.

The power dissipation on the input capacitors can be estimated with the RMS current and the ESR.

Electrolytic or tantalum capacitors can also be used. The input voltage ripple caused by the capacitor can be calculated as:

$$\Delta V_{CIN}=\frac{I_{OUT}}{F_{SW}\cdot C_{IN}}\cdot\frac{V_{OUT}}{V_{IN}}\cdot\left(1-\frac{V_{OUT}}{V_{IN}}\right)$$

in which, $F_{SW}$ is switching frequency of 2.5MHz.

## Output Capacitor Selection

Output capacitors are required to keep output voltage stable. To minimize the output voltage ripple, low ESR ceramic capacitors should be used. The output voltage ripple can be estimated as:

$$\Delta V_{OUT}=\frac{V_{OUT}}{8F_{SW}^2C_{OUT}L}\cdot\left(1-\frac{V_{OUT}}{V_{IN}}\right)$$

In which, L is the inductor fixed at 0.47μH internally.

If electrolytic or tantalum capacitors are used, the ESR will dominate the output voltage ripple as:

$$\Delta V_{OUT}=R_{ESR}\cdot\frac{V_{OUT}}{F_{SW}L}\cdot\left(1-\frac{V_{OUT}}{V_{IN}}\right)$$

## Enable Control

When input voltage is above the under-voltage-lock-out threshold, M0503 can be enabled by pulling the EN pin to above 1.21V and will be disabled if the EN pin is below 1.1V. It is recommended to pull up to VIN with the resister about 100kΩ.

## Power Good Indicator

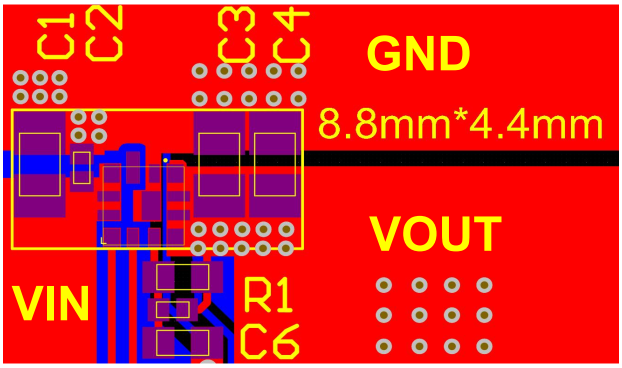
M0503 has an open drain PG indicator. PG will be pulled up if output voltage is within ±10% of regulation, otherwise PG is pulled down by internal NMOS. A pull-up resistor to VIN or VOUT is needed if used and it is recommended to choose the resister about 100kΩ.

## PCB Layout Guide

To optimize the electrical and thermal performance, some PCB layout guidelines should be considered as below:

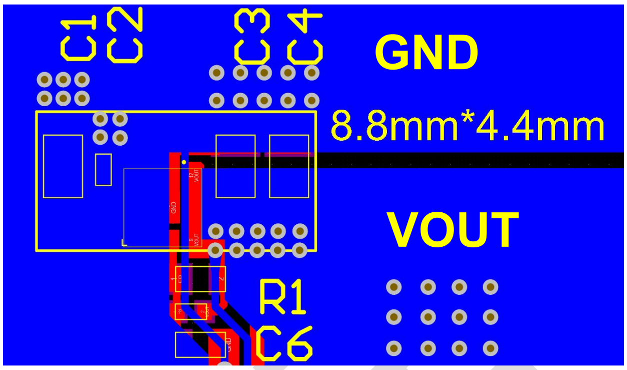
1. Use wide trace for the high current paths and keep it as short as possible. It helps to minimize the PCB conduction loss and thermal stress.
2. Place the input decoupling capacitor close to VIN and GND.
3. Connect all feedback network to FB shortly.

4. Keep the FB network away from the switching node.
5. The GND should be connected to a strong ground plane for better heat dissipation and noise protection.




（a）Top Layer

Figure 1 gives a good example of the recommended layout.




（b）Bottom Layer

Figure 1. Recommended Layout

## TYPICAL APPLICATION

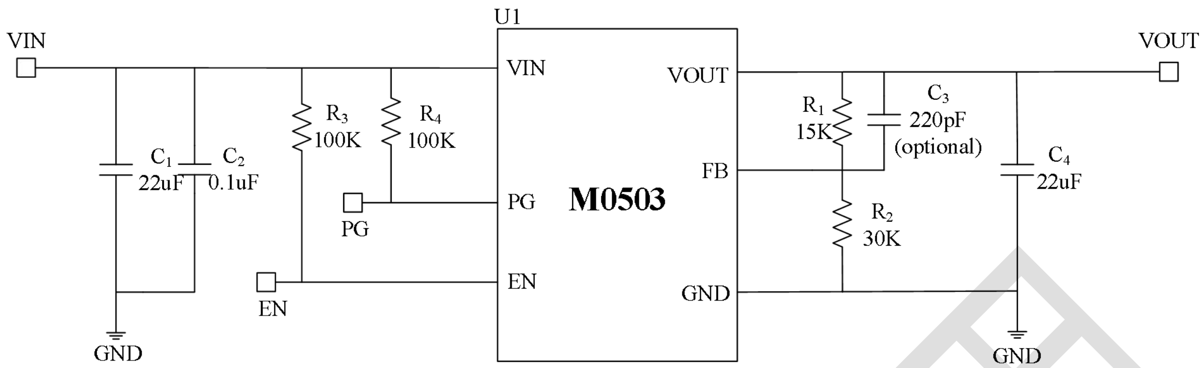



Figure 2. Typical Application Circuits of M0503 for 1.2V@3A Output

**Table 2：Reference Design** Note1)

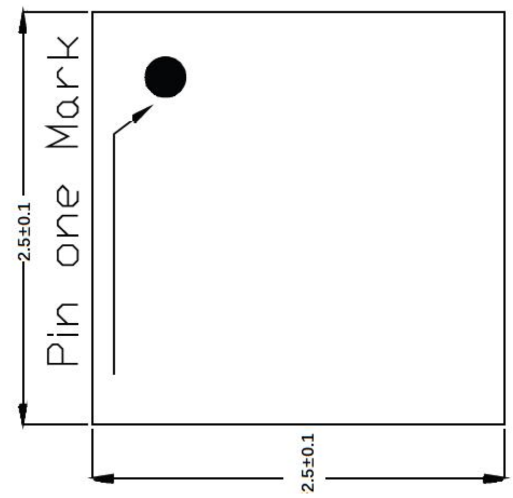
| VOUT(V) | CIN(uF) | COUT(uF) | $R_1$(kΩ) | $R_2$(kΩ) |
|---|---|---|---|---|
| 3.3V Note2) | 10 | 2×10 | 100 | 31.6 |
| 1.8V Note2) | 10 | 2×10 | 37.4 | 30 |
| 1.2V | 10 | 2×10 | 15 | 30 |
| 1.0V | 10 | 2×10 | 7.5 | 30 |

**NOTES：**

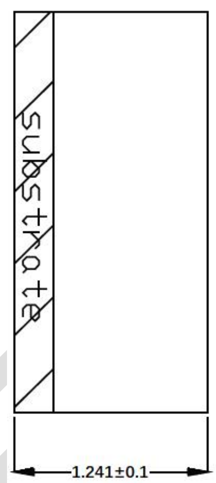
1) CIN is the sum of the input capacitors, COUT is the sum of the output capacitors, please refer to Figure 2 for parameters of other components.
2) $C_3$ is a recommended forward capacitor to improve stability for 1.8V and 3.3V output Voltage condition.

## PACKAGE INFORMATION

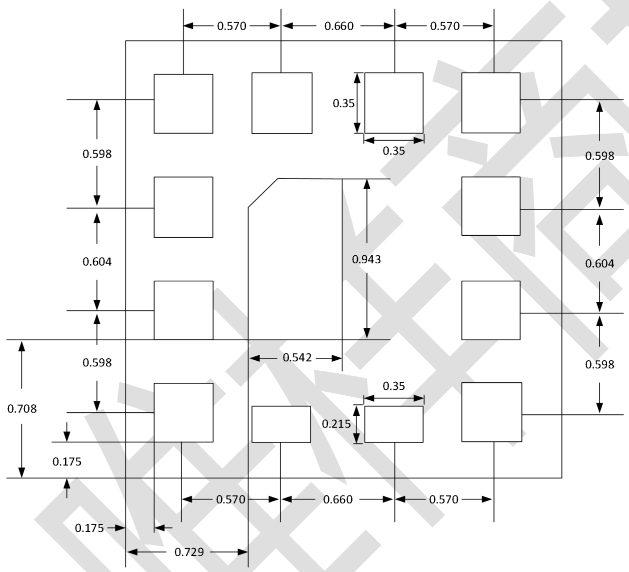
TOP VIEW




SIDE VIEW

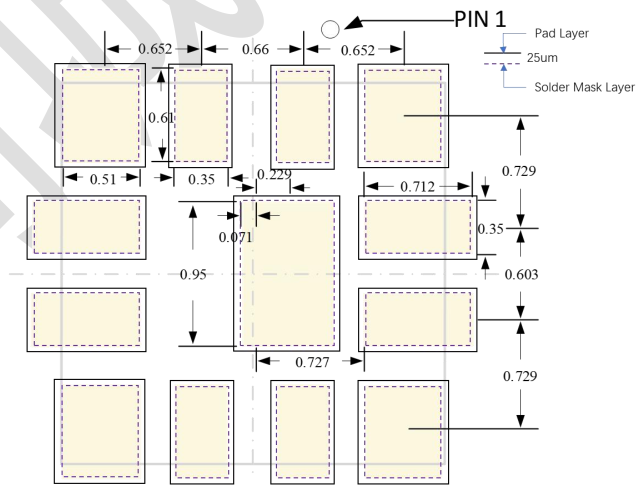



BOTTOM VIEW




**RECOMMENDED LAND PATTERN**

**Prefer Solder Mask Defined**




LGA-13(2.5mm×2.5mm×1.24mm) Package

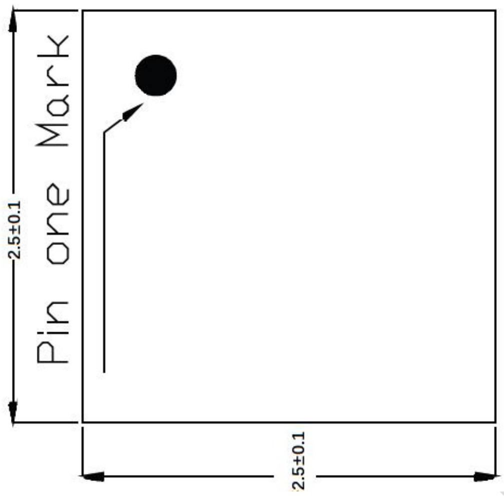
**NOTES:**

All dimensions are in MM.

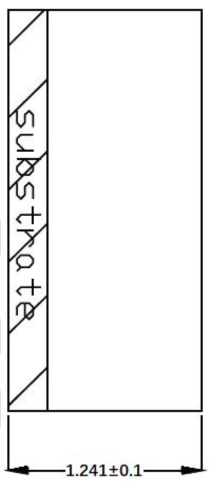
## PACKAGE INFORMATION

LGA-13(2.5mm×2.5mm×1.24mm) Package

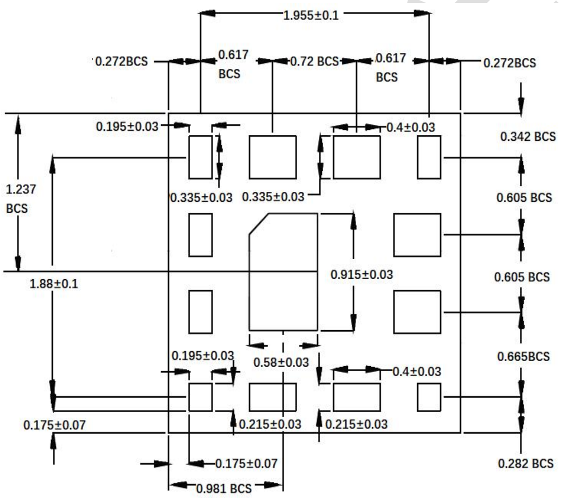
TOP VIEW



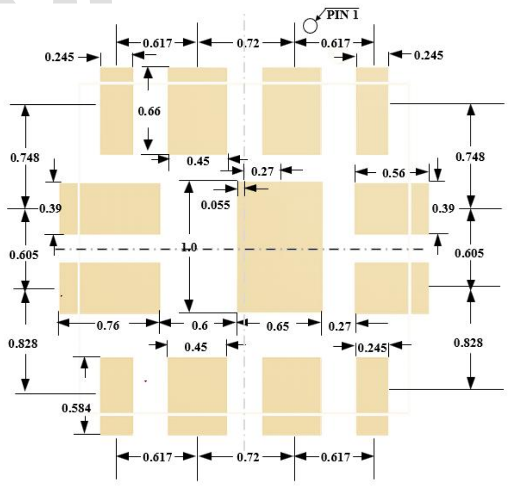

SIDE VIEW




BOTTOM VIEW




**RECOMMENDED LAND PATTERN**

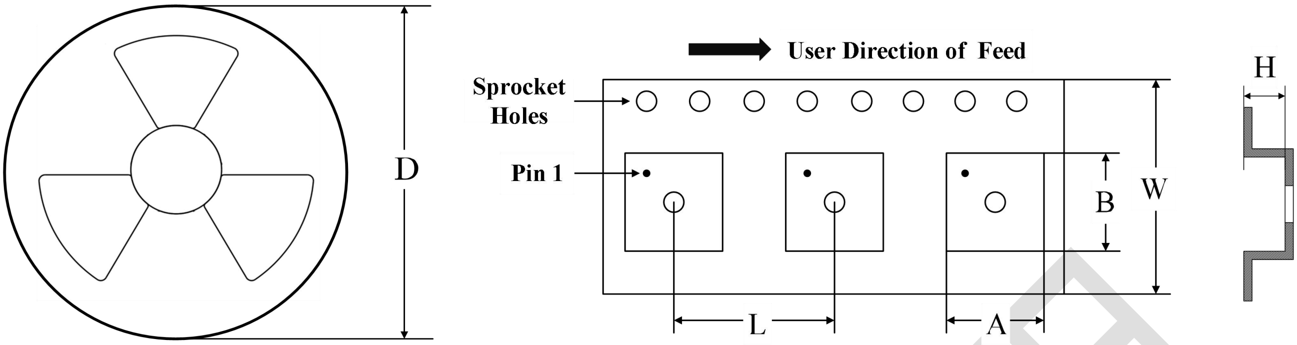



(Not recommended for new design)

**NOTES:**

All dimensions are in MM.

## CARRIER INFORMATION




| PART NUMBER | PACKAGE | QUANTITY /REEL | D | A | B | L | W | H |
|---|---|---|---|---|---|---|---|---|
| M0503DLBGP | LGA-13 (2.5mm×2.5mm×1.24mm) | 3000 | 13 in | 2.7mm | 2.7mm | 8mm | 12mm | 1.5mm |
| M0503DLBG | LGA-13 (2.5mm×2.5mm×1.24mm) | 3000 | 13 in | 2.7mm | 2.7mm | 8mm | 12mm | 1.5mm |

# REVISION HISTORY

| Revision | Date | Record |
|---|---|---|
| Rev1.1 | 2024-03 | Add Solder Mask Defined Information |