**The Future of Analog IC Technology**

# DESCRIPTION

The MP5402 integrates a monolithic, step-down, switch-mode converter with two USB current-limit switches and a charging port identification circuit. The MP5402 achieves 5A of continuous output current with excellent load and line regulation over a wide input supply range.

The output of the USB switch is current-limited. Both USB ports support DCP schemes for the battery charging specification (BC1.2), divider mode, and 1.2V/1.2V mode, eliminating the need for outside user interaction.

The output voltage has programmable line drop compensation.

Full protection features include hiccup current limiting, output over-voltage protection (OVP), and thermal shutdown.

The MP5402 requires a minimal number of readily available, standard, external components and is available in a QFN-26 (4mmx4mm) package.
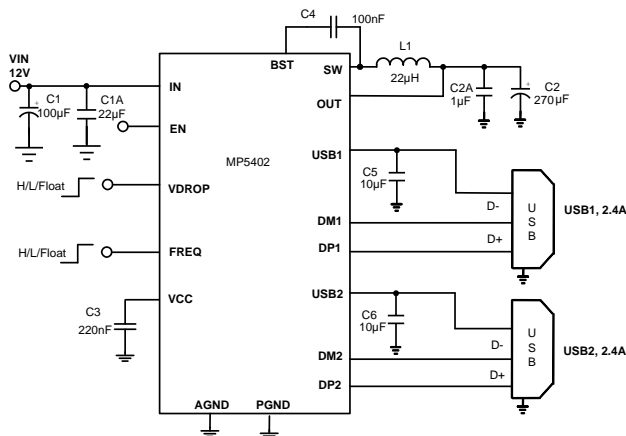
# FEATURES

- Wide 7V to 36V Operating Input Voltage Range
- Fixed 5V Output Voltage with Line Drop Compensation
- Accurate USB1/USB2 Output Current Limit
- 40mΩ/32mΩ Low-$R_{DS(ON)}$ Internal Buck Power MOSFETs
- 24mΩ/24mΩ Low-$R_{DS(ON)}$ Internal USB1/USB2 Power MOSFETs
- 350kHz / 250kHz / 150kHz Frequency Selectable
- Programmable Line Drop Compensation
- Output Over-Voltage Protection (OVP)
- Hiccup Current Limit
- Supports DCP Schemes for BC1.2, Divider Mode, and 1.2V/1.2V Mode
- ±8kV HBM ESD Rating for USB, DP, and DM
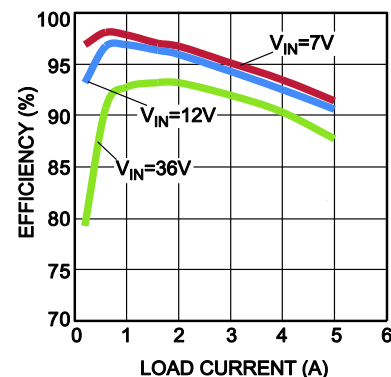- Available in a QFN-26 (4mmx4mm) Package

# APPLICATIONS

- USB Dedicated Charging Ports (DCP)
- Smart Cigarette Lighter Adapter USB Chargers

# TYPICAL APPLICATION



Efficiency vs. Load Current

## ORDERING INFORMATION

| Part Number* | Package | Top Marking |
|---|---|---|
| MP5402GR | QFN-26 (4mmx4mm) | *See Below* |

\* For Tape & Reel, add suffix –Z (e.g. MP5402GR–Z).

## TOP MARKING

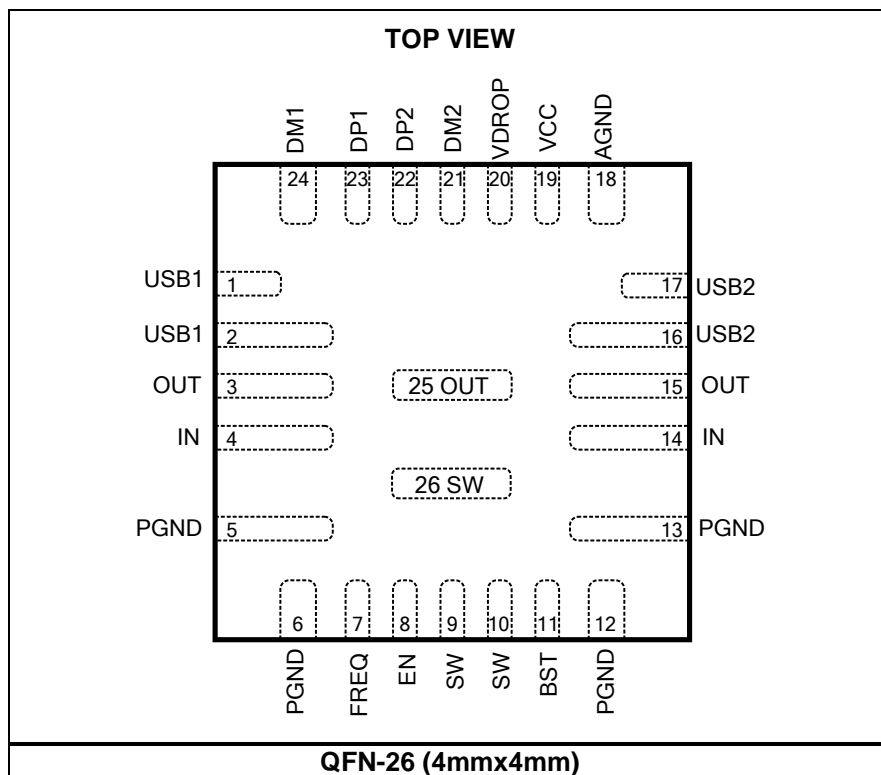MPSYWW

MP5402

LLLLLL

MPS: MPS prefix
Y: Year code
WW: Week code
MP5402: Part number
LLLLLL: Lot number

## PACKAGE REFERENCE

## ABSOLUTE MAXIMUM RATINGS [1]

Supply voltage ($V_{IN}$) ..................................... 40V
$V_{SW}$................................... -0.3V (-5V for <10ns)
    to $V_{IN}$ + 0.3V (43V for <10ns)
$V_{BST}$ ................................................... $V_{SW}$ + 6.5V
$V_{EN}$ .............................................. -0.3V to 10V [2]
All other pins ................................-0.3V to +6.5V
Continuous power dissipation ($T_A$ = +25°C) [3]
QFN-26 (4mmx4mm) ................................ 2.8W
Junction temperature ...............................150°C
Lead temperature .....................................260°C
Storage temperature............... -65°C to +150°C

### Recommended Operating Conditions [4]

Operation input voltage range ............7V to 36V
Output current.....2.4A for USB1, 2.4A for USB2
Operating junction temp. ($T_J$)... -40°C to +125°C

### Thermal Resistance [5]   $\theta_{JA}$    $\theta_{JC}$

QFN-26 (4mmx4mm)............. 44........ 9.... °C/W

**NOTES:**
1) Exceeding these ratings may damage the device.
2) For details on EN's ABS max rating, please refer to the EN Control section on page 11.
3) The maximum allowable power dissipation is a function of the maximum junction temperature $T_J$ (MAX), the junction-to-ambient thermal resistance $\theta_{JA}$, and the ambient temperature $T_A$. The maximum allowable continuous power dissipation at any ambient temperature is calculated by $P_D$ (MAX) = ($T_J$ (MAX)-$T_A$)/$\theta_{JA}$. Exceeding the maximum allowable power dissipation produces an excessive die temperature, causing the regulator to go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.
4) The device is not guaranteed to function outside of its operating conditions.
5) Measured on JESD51-7, 4-layer PCB.

## ELECTRICAL CHARACTERISTICS

$V_{IN}$ = 12V, $V_{EN}$ = 5V, $T_J$ = -40°C to +125°C [6]. Typical value is tested at $T_J$ = +25°C unless otherwise noted.

| Parameter | Symbol | Condition | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| Supply current (shutdown) | $I_{IN}$ | $V_{EN}$ = 0V, $T_J$ = +25°C | | | 1 | μA |
| | | $V_{EN}$ = 0V, $T_J$ = -40°C to +125°C | | | 5 | |
| Supply current (quiescent) | $I_{Q\_OL}$ | No switching | | 1.6 | 2.5 | mA |
| EN rising threshold | $V_{EN\_Rising}$ | | 1.33 | 1.43 | 1.52 | V |
| EN hysteresis | $V_{EN\_Falling}$ | | 110 | 140 | 170 | mV |
| EN input current | $I_{EN}$ | $V_{EN}$ = 2V, $T_J$ = +25°C | 1.1 | 1.8 | 2.5 | μA |
| | | $V_{EN}$ = 2V, $T_J$ = -40°C to +125°C | 0.8 | 1.8 | 3 | |
| | | $V_{EN}$ = 0V | | 0 | | |
| Thermal shutdown [7] | $T_{STD}$ | | | 165 | | °C |
| Thermal hysteresis [7] | $T_{STD\_HYS}$ | | | 20 | | °C |
| VCC regulator | $V_{CC}$ | | 4.75 | 5.1 | 5.45 | V |
| VCC load regulation | $V_{CC\_LOG}$ | $I_{CC}$ = 5mA | | 1 | 2 | % |
| **Step-Down Converter** | | | | | | |
| $V_{IN}$ under-voltage lockout threshold rising | $V_{IN\_UVLO}$ | $T_J$ = +25°C | 5.2 | 5.7 | 6.2 | V |
| $V_{IN}$ under-voltage lockout threshold hysteresis | $V_{UVLO\_HYS}$ | | | 1 | | V |
| HS switch-on resistance | $R_{DSON\_HS}$ | | | 40 | | mΩ |
| LS switch-on resistance | $R_{DSON\_LS}$ | | | 32 | | mΩ |
| Output voltage | $V_{OUT}$ | 7V < $V_{IN}$ < 36V, no load, $T_J$ = +25°C | 5 | 5.05 | 5.1 | V |
| | | 7V < $V_{IN}$ < 36V, no load, $T_J$ = -40°C to +125°C | 4.95 | 5.05 | 5.15 | |
| Output over-voltage protection (OVP) | $V_{OVP\_R}$ | | 5.65 | 6 | 6.4 | V |
| OVP recovery | $V_{OVP\_F}$ | $T_J$ = -40°C to +125°C | 5.4 | 5.75 | 6.1 | V |
| Switch leakage | $SW_{LKG}$ | $V_{EN}$ = 0V, $V_{SW}$ = 36V or 0V, $T_J$ = +25°C | | | 1 | μA |
| | | $V_{EN}$ = 0V, $V_{SW}$ = 36V or 0V, $T_J$ = -40°C to +125°C | | | 5 | |
| Current limit [7] | $I_{LIMIT}$ | 40% duty cycle | | 8.5 | | A |
| Oscillator frequency | $f_{SW1}$ | FREQ = high, $T_J$ = +25°C | 310 | 350 | 410 | kHz |
| | | FREQ = high, $T_J$ = -40°C to +125°C | 300 | 350 | 420 | |
| | $f_{SW2}$ | FREQ = low, $T_J$ = +25°C | 220 | 250 | 300 | |
| | | FREQ = low, $T_J$ = -40°C to +125°C | 190 | 250 | 330 | |
| | $f_{SW3}$ | FREQ = float, $T_J$ = +25°C | 125 | 150 | 180 | |
| | | FREQ = float, $T_J$ = -40°C to +125°C | 110 | 150 | 185 | |
| Maximum duty cycle | $D_{MAX}$ | FREQ = 350kHz | 84 | 88 | | % |
| Minimum on time [7] | $T_{ON\_MIN}$ | $T_J$ = +25°C | | 130 | | ns |
| Soft-start time | $t_{SS}$ | Output from 10% to 90%, $T_J$ = +25°C | 1 | 1.65 | 2.3 | ms |
| | | Output from 10% to 90%, $T_J$ = -40°C to +125°C | 0.9 | 1.65 | 2.4 | |

## ELECTRICAL CHARACTERISTICS *(continued)*

$V_{IN}$ = 12V, $V_{EN}$ = 5V, $T_J$ = -40°C to +125°C [6]. **Typical value is tested at $T_J$ = +25°C unless otherwise noted.**

| Parameter | Symbol | Condition | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| **USB Switch** | | | | | | |
| Under-voltage lockout threshold rising | $V_{USB\_UVR}$ | $T_J$ = +25°C | 3.8 | 4 | 4.3 | V |
| | | $T_J$ = -40°C to +125°C | 3.75 | 4 | 4.33 | |
| Under-voltage lockout threshold hysteresis | $V_{USB\_UVHYS}$ | | 220 | 270 | 320 | mV |
| Switch-on resistance | $R_{DSON\_SW}$ | | | 24 | | mΩ |
| Current limit | $I_{Limit}$ | $T_J$ = +25°C | 2.6 | 2.75 | 2.9 | A |
| Line drop compensation | $V_{DROP\_COM1}$ | Max load 2.4A, $V_{DROP}$ = float, $T_J$ = +25°C | 300 | 400 | 500 | mV |
| | $V_{DROP\_COM2}$ | Max load 2.4A, $V_{DROP}$ = high | | 280 | | mV |
| | $V_{DROP\_COM3}$ | Max load 2.4A, $V_{DROP}$ = GND | | 130 | | mV |
| FREQ, VDROP high level | $V_{HIGH}$ | | $V_{CC}$-0.4V | | | V |
| FREQ, VDROP middle level | $V_{MIDDLE}$ | | | 2.5 | | V |
| FREQ, VDROP low level | $V_{LOW}$ | | | | 0.4 | V |
| $V_{BUS}$ soft-start time | $T_{SS}$ | $V_{OUT}$ = 5V, from 10% to 90%, $T_J$ = +25°C | 1 | 1.6 | 2.2 | ms |
| | | $V_{OUT}$ = 5V, from 10% to 90%, $T_J$ = -40°C to +125°C | 0.9 | 1.6 | 2.4 | |
| Discharge resistance | $R_{DCHG}$ | $T_J$ = +25°C | | 50 | 70 | Ω |
| | | $T_J$ = -40°C to +125°C | | 50 | 75 | |
| Hiccup mode on time | $T_{HICP\_ON1}$ | $V_{OUT}$ = 5V, $V_{BUS}$ connected to GND | | 3[7] | | ms |
| | $T_{HICP\_ON2}$ | $V_{OUT}$ = 5V, $V_{BUS}$ > 2V, OC, $T_J$ = +25°C | 3.5 | 5 | 6.5 | |
| | | $V_{OUT}$ = 5V, $V_{BUS}$ > 2V, OC, $T_J$ = -40°C to +125°C | 3 | 5 | 7 | |
| Hiccup mode off time | $T_{HICP\_OFF}$ | $V_{OUT}$ = 5V, $V_{BUS}$ connected to GND, $T_J$ = +25°C | 6.5 | 8.5 | 10.5 | s |
| | | $V_{OUT}$ = 5V, $V_{BUS}$ connected to GND, $T_J$ = -40°C to +125°C | 6 | 8.5 | 11 | |
| **BC1.2 DCP Mode** | | | | | | |
| DP and DM short resistance | $R_{DP/DM\_Short}$ | $V_{DP}$ = 0.8V, $I_{DM}$ = 1mA, $T_J$ = +25°C | | 125 | 155 | Ω |
| | | $V_{DP}$ = 0.8V, $I_{DM}$ = 1mA, $T_J$ = -40°C to +125°C | | 125 | 160 | |
| **Divider Mode** | | | | | | |
| DP/DM output voltage | $V_{DP/DM\_Divider}$ | $V_{OUT}$ = 5V, $T_J$ = +25°C | 2.54 | 2.7 | 2.82 | V |
| | | $V_{OUT}$ = 5V, $T_J$ = -40°C to +125°C | 2.5 | 2.7 | 2.85 | |
| DP/DM output impedance | $R_{DP/DM\_Divider}$ | $T_J$ = +25°C | 20 | 22 | 23 | kΩ |
| | | $T_J$ = -40°C to +125°C | 18 | 22 | 28 | |

## ELECTRICAL CHARACTERISTICS *(continued)*
$V_{IN}$ = 12V, $V_{EN}$ = 5V, $T_J$ = -40°C to +125°C [6]. Typical value is tested at $T_J$ = +25°C unless otherwise noted.

| Parameter | Symbol | Condition | Min | Typ | Max | Units |
|-----------|--------|-----------|-----|-----|-----|-------|
| **1.2V/1.2V Mode** | | | | | | |
| DP/DM output voltage | $V_{DP/DM\_1.2V}$ | $V_{OUT}$ = 5V, $T_J$ = +25°C | 1.16 | 1.25 | 1.34 | V |
| | | $V_{OUT}$ = 5V, $T_J$ = -40°C to +125°C | 1.15 | 1.25 | 1.35 | |
| DP/DM output impedance | $R_{DP/DM\_1.2V}$ | $T_J$ = +25°C | 60 | 68 | 75 | kΩ |
| | | $T_J$ = -40°C to +125°C | 55 | 68 | 88 | |

**NOTES:**
6) All min/max parameters are tested at $T_J$ = 25°C. Limits over temperature are guaranteed by design, characterization, and correlation.
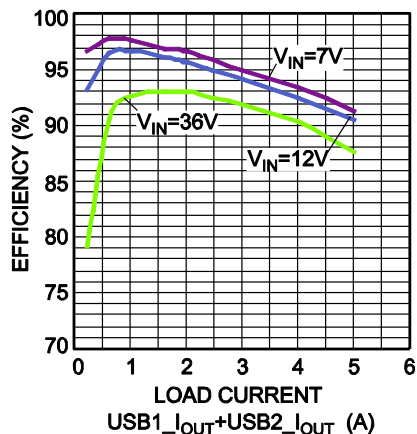7) Guaranteed by design.

## TYPICAL PERFORMANCE CHARACTERISTICS

$V_{IN}$ = 12V, $V_{OUT}$ = 5V, L = 22µH, $T_A$ = 25°C, unless otherwise noted.

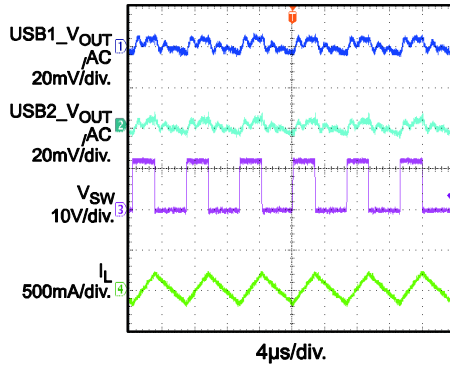**Line Drop Compensation vs. Load Current**
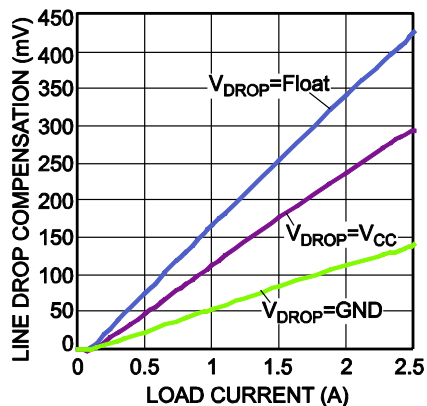


**Efficiency vs. Load Current**

# TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

$V_{IN}$ = 12V, $V_{OUT}$ = 5V, L = 22µH, $T_A$ = 25°C, unless otherwise noted.

**Output Ripple**
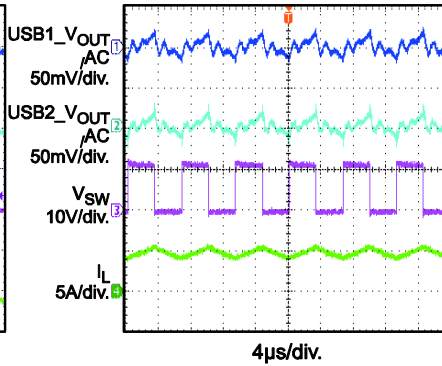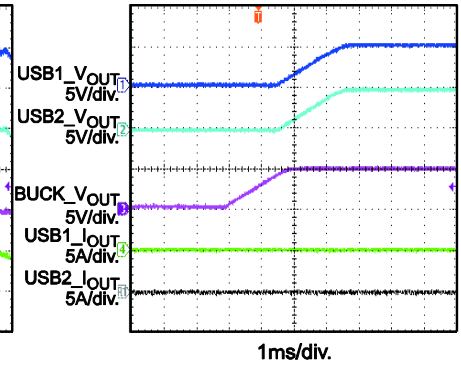$V_{IN}$ = 12V, $V_{OUT}$ = 5V,
USB1_$I_{OUT}$ = USB2_$I_{OUT}$ = 0A

**Output Ripple**
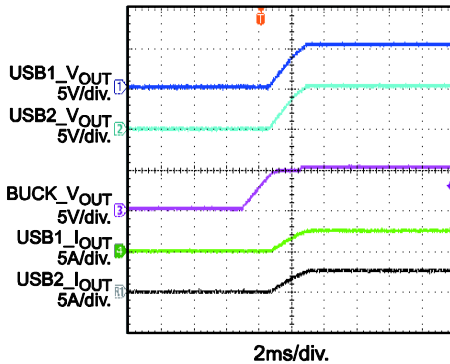$V_{IN}$ = 12V, $V_{OUT}$ = 5V,
USB1_$I_{OUT}$ = USB2_$I_{OUT}$ = 2.4A

**Power Start-Up**
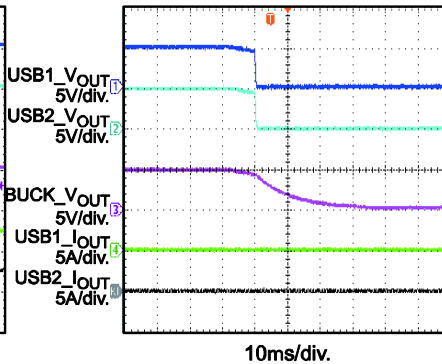$V_{IN}$ = 12V, $V_{OUT}$ = 5V,
USB1_$I_{OUT}$ = USB2_$I_{OUT}$ = 0A

**Power Start-Up**
$V_{IN}$ = 12V, $V_{OUT}$ = 5V,
USB1_$I_{OUT}$ = USB2_$I_{OUT}$ = 2.4A,
CRL Load

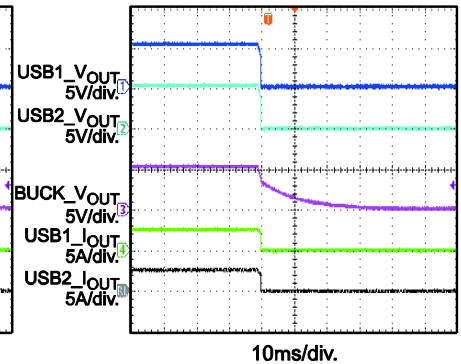**Power Shutdown**
$V_{IN}$ = 12V, $V_{OUT}$ = 5V,
USB1_$I_{OUT}$ = USB2_$I_{OUT}$ = 0A

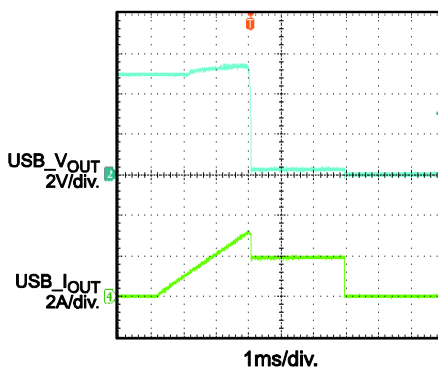**Power Shutdown**
$V_{IN}$ = 12V, $V_{OUT}$ = 5V,
USB1_$I_{OUT}$ = USB2_$I_{OUT}$ = 2.4A,
CRL Load

**USB Over-Current
Protection**

## PIN FUNCTIONS

| QFN 4x4 Pin # | Name | Description |
|---|---|---|
| 1, 2 | USB1 | **USB1 output.** |
| 3, 15, 25 | OUT | **Buck output.** OUT is the power input for USB1 and USB2. The internal circuit senses the OUT voltage and regulates it at 5V. |
| 4, 14 | IN | **Supply voltage.** IN is the drain of the internal power device and provides power to the entire chip. The MP5402 operates on a 7V to 36V input voltage. A capacitor ($C_{IN}$) prevents large voltage spikes from appearing at the input. Place $C_{IN}$ as close to the IC as possible. |
| 5, 6, 12, 13 | PGND | **Power ground.** PGND is the reference ground of the regulated output voltage. PGND requires extra care during the PCB layout. Connect PGND to GND with copper traces and vias. |
| 7 | FREQ | **Frequency selection.** Floating FREQ sets the frequency at 150kHz. Pulling FREQ to ground sets the frequency at 250kHz. Pulling FREQ to 5V sets the frequency at 350kHz. |
| 8 | EN | **On/off control input.** |
| 9, 10, 26 | SW | **Switch output.** Use a wide PCB trace to make the connection. |
| 11 | BST | **Bootstrap.** Connect a 0.1µF capacitor between SW and BST to form a floating supply across the high-side switch driver. |
| 16, 17 | USB2 | **USB2 output.** |
| 18 | AGND | **Analog ground.** Connect AGND to PGND. |
| 19 | VCC | **Internal 5V LDO regulator output.** Decouple VCC with a 0.22µF capacitor. |
| 20 | VDROP | **Line drop compensation selection.** Refer to the EC table on page 5 for detailed specifications. |
| 21 | DM2 | **D- data line to USB connector.** DM2 is the input/output used for handshaking with portable devices. |
| 22 | DP2 | **D+ data line to USB connector.** DP2 is the input/output used for handshaking with portable devices. |
| 23 | DP1 | **D+ data line to USB connector.** DP1 is the input/output used for handshaking with portable devices. |
| 24 | DM1 | **D- data line to USB connector.** DM1 is the input/output used for handshaking with portable devices. |

# BLOCK DIAGRAM
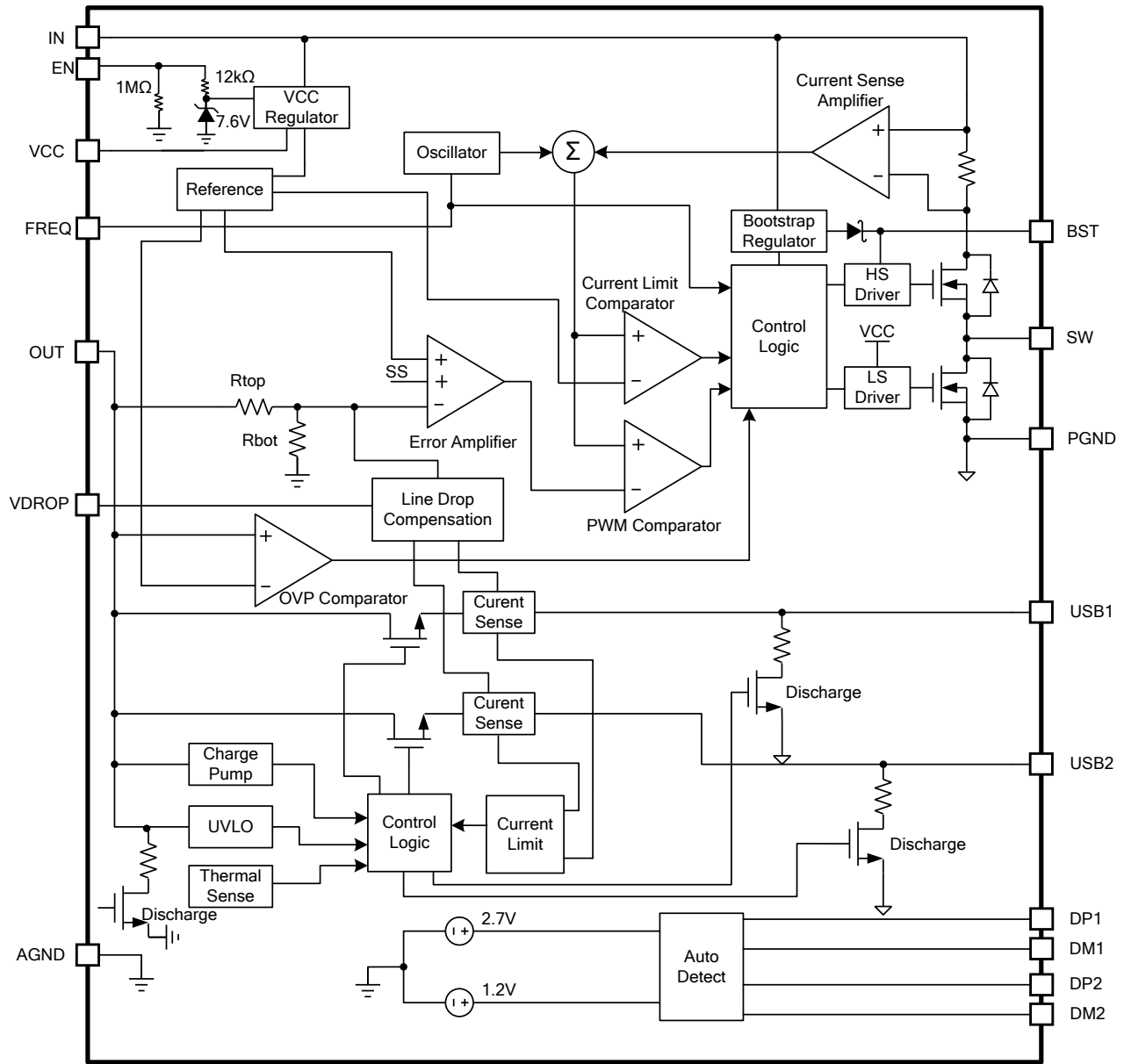
**Figure 1: Functional Block Diagram**

# OPERATION

## BUCK CONVERTER SECTION

The MP5402 integrates a monolithic, synchronous, rectified, step-down, switch-mode converter with internal power MOSFETs and two USB current-limit switches with charging port auto-detection. The MP5402 offers a compact solution that achieves 5A of continuous output current with excellent load and line regulation over a wide input supply range.

The MP5402 operates in fixed-frequency, peak-current-mode control to regulate the output voltage. The internal clock initiates the pulse-width modulation (PWM) cycle, which turns on the integrated high-side power MOSFET (HS-FET). The HS-FET remains on until its current reaches the value set by the COMP voltage ($V_{COMP}$). When the power switch is off, it remains off until the next clock cycle begins. If the duty cycle reaches 88% (350kHz switching frequency) in one PWM period, the current in the power MOSFET will not reach the COMP-set current value, and the power MOSFET turns off.

## Error Amplifier (EA)

The error amplifier (EA) compares the internal feedback voltage ($V_{FB}$) against the internal 1V reference (REF) and outputs a $V_{COMP}$ value. This $V_{COMP}$ controls the power MOSFET current. The optimized internal compensation network minimizes the external component count and simplifies the control loop design.

## Internal VCC Regulator

The 5V internal regulator powers most of the internal circuitries. This regulator takes $V_{IN}$ and operates in the full $V_{IN}$ range. When $V_{IN}$ exceeds 5.0V, the output of the regulator is in full regulation. If $V_{IN}$ is less than 5.0V, the output decreases with $V_{IN}$. VCC requires an external 0.22µF ceramic decoupling capacitor.

## Enable Control (EN)

The MP5402 has an enable control pin (EN). Pulling EN high enables the IC. Pulling EN low disables the IC. Connect EN to $V_{IN}$ through a resistor for automatic start-up. An internal 1MΩ resistor from EN to GND allows EN to be floated to shut down the IC. EN is clamped internally using a 7.6V series Zener diode (see Figure 2). Connect EN through a pull-up resistor to any voltage connected to $V_{IN}$. This requires limiting the amplitude of the voltage source below 10V and the EN input current less than 230µA to prevent damage to the Zener diode.

For example, if connecting 36V to $V_{IN}$, then $R_{PULLUP} \geq$ (36V - 10V) / 230µA = 113kΩ.
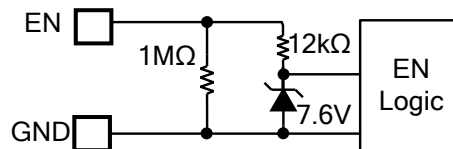


**Figure 2: Zener Diode between EN and GND**

## Under-Voltage Lockout (UVLO)

Under-voltage lockout (UVLO) protects the chip from operating at an insufficient supply voltage. The UVLO comparator monitors the input voltage. The UVLO rising threshold is 5.7V, and its falling threshold is 4.7V.

## Internal Soft Start (SS)

Soft start (SS) prevents the converter output voltage from overshooting during start-up. When the chip starts up, the internal circuitry generates a SS voltage that ramps up from 0V to 5V. When SS is lower than REF, the error amplifier uses SS as the reference. When SS is higher than REF, the error amplifier uses REF as the reference. The SS time is set to 1.65ms internally.

If the output of the MP5402 is pre-biased to a certain voltage during start-up, the IC disables the switching of both the high-side and low-side switches until the voltage on the internal SS capacitor exceeds the internal feedback voltage.

## Buck Over-Current Protection (OCP)

The MP5402 implements a cycle-by-cycle, over-current limit when the inductor peak current exceeds the current-limit threshold and $V_{FB}$ drops below the under-voltage (UV) threshold (typically 70% below the reference). Once UV is triggered, the MP5402 enters hiccup mode to restart the part periodically. This protection mode is especially useful when the output is dead-shorted to ground. This reduces the average short-circuit current greatly, alleviating thermal issues and protecting the

regulator. The MP5402 exits hiccup mode once the over-current condition is removed.

### Buck Output Over-Voltage Protection (OVP)

The MP5402 has an output over-voltage protection (OVP). If the output rises higher than 6V, the high-side switch stops switching, and the low-side switch turns on to discharge the output voltage until the output decreases to 5.75V. The chip then resumes normal operation. If the output over voltage cannot be discharged to 5.75V, the low-side switch turns off after the inductor current reaches a negative current limit. The low-side switch turns on again when the next clock cycle begins.

### Floating Driver and Bootstrap Charging

An external bootstrap capacitor powers the floating power MOSFET driver. This floating driver has its own UVLO protection. The UVLO's rising threshold is 2.2V with a hysteresis of 150mV. The bootstrap capacitor voltage is regulated internally by $V_{IN}$ through D1, M1, C4, L1, and C2 (see Figure 3). If $V_{BST}$ - $V_{SW}$ exceeds 5V, U1 regulates M1 to maintain a 5V BST voltage across C4.
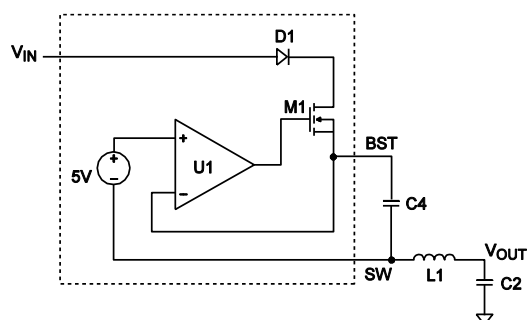


**Figure 3: Internal Bootstrap Charging Circuit**

### Start-Up and Shutdown

If both $V_{IN}$ and EN exceed their respective thresholds, the chip is enabled. The reference block starts first, generating a stable reference voltage and current, and then the internal regulator is enabled. The regulator provides a stable supply for the remaining circuitries.

Three events can shut down the chip: EN low, $V_{IN}$ low, and thermal shutdown. During shutdown, the signaling path is blocked to avoid any fault triggering, and $V_{COMP}$ and the internal supply rail are pulled down. The floating driver is not subject to this shutdown command.

### Buck Output Discharge

The buck portion of the device involves a discharge function that provides a resistive discharge path for the external output capacitor. The function is active when the part is disabled (input voltage is under UVLO, EN off) and is done in a very limited amount of time. After VCC discharges below 1V, the buck output discharge resistor disconnects.

## USB CURRENT-LIMIT SWITCH

### Current-Limit Switch

The MP5402 integrates two USB current-limit switches. It provides built-in soft-start circuitry, which controls the rising slew rate of the output voltage to limit the inrush current and voltage surges.

When the load current reaches the current-limit threshold (typically 2.75A), the USB power MOSFET switches to foldback current-limit mode, 70% of the current limit (see Figure 4). If the over-current limit condition lasts longer than 3ms, the USB channel enters hiccup mode with 3ms of on time and 8.5s of off time.
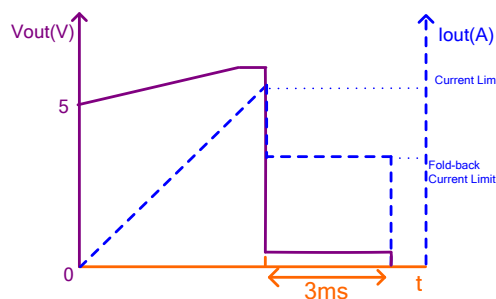


**Figure 4: Over-Current Limit**

During $V_{IN}$ or EN start-up, ensure that the CC load current does not exceed 70% of the current limit to avoid triggering a foldback current limit and start-up failure.

### Output Line Drop Compensation

The MP5402 can compensate for an output-voltage drop, such as high impedance caused by a long trace, to maintain a fairly constant 5V load-side voltage.

The internal comparator compares the current-sense output voltage of the two current-limit switches and uses the larger current-sense output voltage to compensate for the line drop voltage.

Since the trace resistance varies for different cables, the MP5402 provides selectable line drop compensation through VDROP. The line drop compensation amplitude increases linearly as the load current increases and also has an upper limitation.

## USB Output Over-Voltage Protection (OVP)

To protect the device at the cable terminal, each USB switch output has an independently dynamic over-voltage protection (OVP) threshold. Based on different USB loading currents, the MP5402 adjusts the OVP threshold accordingly.

The intelligent line drop compensation and dynamic OVP control scheme ensure that the voltage at the cable terminal meets the 4.75 - 5.25V specification.

## USB Output Discharge

Each USB portion involves a discharge function that provides a resistive discharge path for the external output capacitor. The function is active when the part is disabled (input voltage is under UVLO, EN off) and is done in a very limited amount of time.

## Auto-Detection

The MP5402 integrates a USB-dedicated charging port auto-detect function. This function recognizes the following mainstream portable devices:

- USB battery charging specification BC1.2/ Chinese telecommunications industry standard YD/T 1591-2009
- Divider mode
- 1.2V/1.2V mode

The auto-detect function is a state machine that supports all of the DCP charging schemes above.

## Thermal Shutdown

Thermal shutdown prevents the chip from operating at exceedingly high temperatures. When the silicon die temperature exceeds 165°C, the entire chip shuts down. When the temperature falls below its lower threshold (typically 145°C), the chip is enabled.

# APPLICATION INFORMATION

## Selecting the Inductor

For most applications, an inductor with a DC current rating at least 25% higher than the maximum load current is recommended. Select an inductor with a small DC resistance for optimum efficiency. The inductor value for most designs can be derived from Equation (1):

$$L_1 = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{V_{IN} \times \Delta I_L \times f_{OSC}} \qquad (1)$$

Where $\Delta I_L$ is the inductor ripple current.

Set the inductor ripple current to approximately 30% of the maximum load current. The maximum inductor peak current can be calculated with Equation (2):

$$I_{L(MAX)} = I_{LOAD} + \frac{\Delta I_L}{2} \qquad (2)$$

A 22µH inductance is recommended to improve EMI.

## Selecting the Buck Input Capacitor

The input current to the step-down converter is discontinuous and therefore requires a capacitor to supply AC current while maintaining the DC input voltage. Low ESR capacitors are recommended for the best performance. Ceramic capacitors with X5R or X7R dielectrics are highly recommended because of their low ESR and small temperature coefficients. For CLA applications, a 100µF electrolytic capacitor, two 10µF ceramic capacitors and two 0.1µF decouple ceramic capacitors are recommended for EMI reduction.

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 with Equation (3):

$$I_{C1} = I_{LOAD} \times \sqrt{\frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)} \qquad (3)$$

The worst-case condition occurs at $V_{IN} = 2V_{OUT}$, shown in Equation (4):

$$I_{C1} = \frac{I_{LOAD}}{2} \qquad (4)$$

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

The input capacitor can be electrolytic, tantalum, or ceramic. When using an electrolytic capacitor, place two, additional, high-quality ceramic capacitors as close to $V_{IN}$ as possible. Estimate the input voltage ripple caused by the capacitance with Equation (5):

$$\Delta V_{IN} = \frac{I_{LOAD}}{f_S \times C1} \times \frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \qquad (5)$$

## Selecting the Buck Output Capacitor

The device requires an output capacitor (C2) to maintain the DC output voltage. Estimate the output voltage ripple with Equation (6):

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_S \times L_1} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times \left(R_{ESR} + \frac{1}{8 \times f_S \times C2}\right) \qquad (6)$$

Where $L_1$ is the inductor value, and $R_{ESR}$ is the equivalent series resistance (ESR) value of the output capacitor.

For an electrolytic capacitor, ESR dominates the impedance at the switching frequency. For simplification, the output ripple can be approximated with Equation (7):

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_S \times L_1} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times R_{ESR} \qquad (7)$$

The characteristics of the output capacitor affect the stability of the regulatory system. A low ESR electrolytic capacitor is recommended for low output ripple and good control loop stability. For a CLA application, a 1µF ceramic capacitor and a 270µF polymer/electrolytic capacitor with ~20mΩ ESR are recommended.

## PCB Layout Guidelines [8]

Efficient PCB layout is critical for achieving stable operation and thermal dissipation. For best results, refer to Figure 5 and follow the guidelines below.

1. Use short, direct, and wide traces to connect OUT.

2. Add vias under the IC.

3. Route the OUT trace on both PCB layers.

4. Use a large copper plane for PGND.

5. Add multiple vias to improve thermal dissipation.

6. Connect AGND to PGND.

7. Use a large copper plane for SW, USB1, and USB2.

8. Route the USB1 and USB2 traces on both PCB layers.

9. Add multiple vias.

10. Place two ceramic input decoupling capacitors as close as possible to IN and PGND to improve EMI performance.

11. Place a VCC decoupling capacitor as close to VCC as possible.

**NOTE:**

8) The recommended layout is based on the Typical Application Circuit shown in Figure 6.

**Top Layer**

**Mid Layer 1**

**Mid Layer 2**

**Bottom Layer**
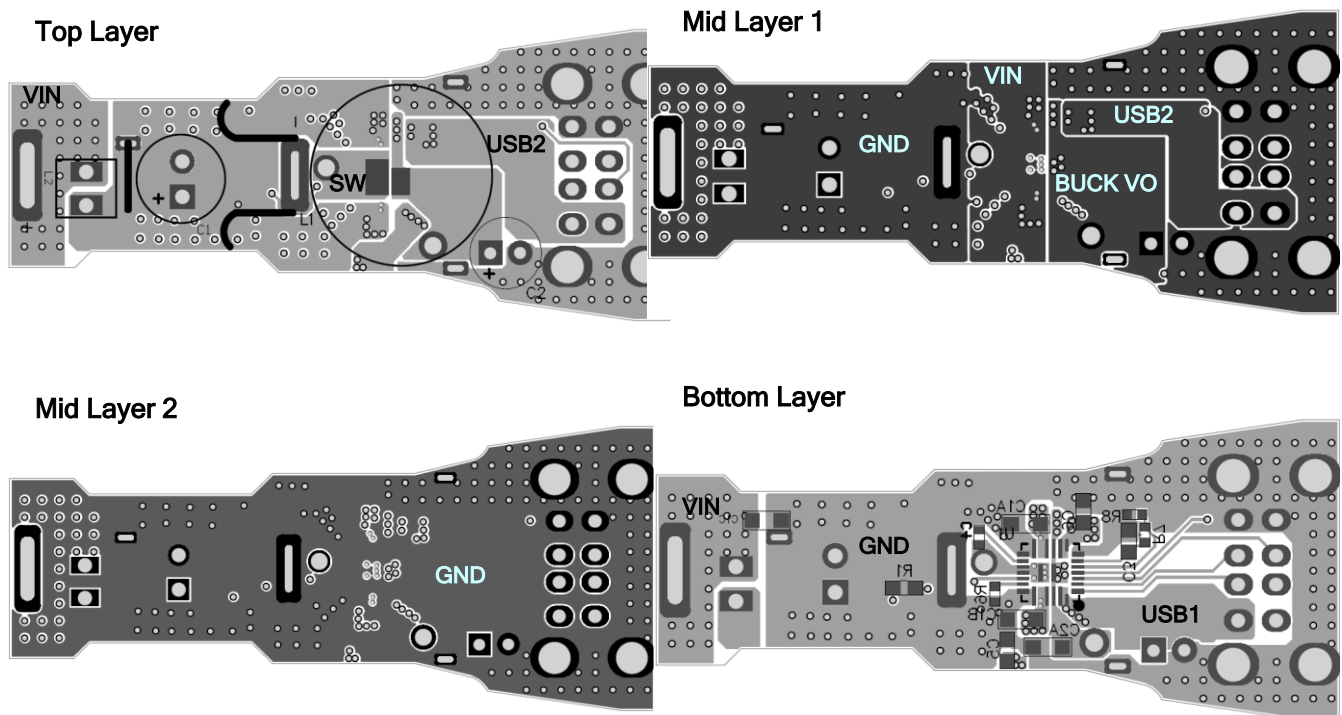


**(4.78cm x 1.38cm)**
**For CLA applications (4-layer), 2Oz per layer PCBA is recommended**
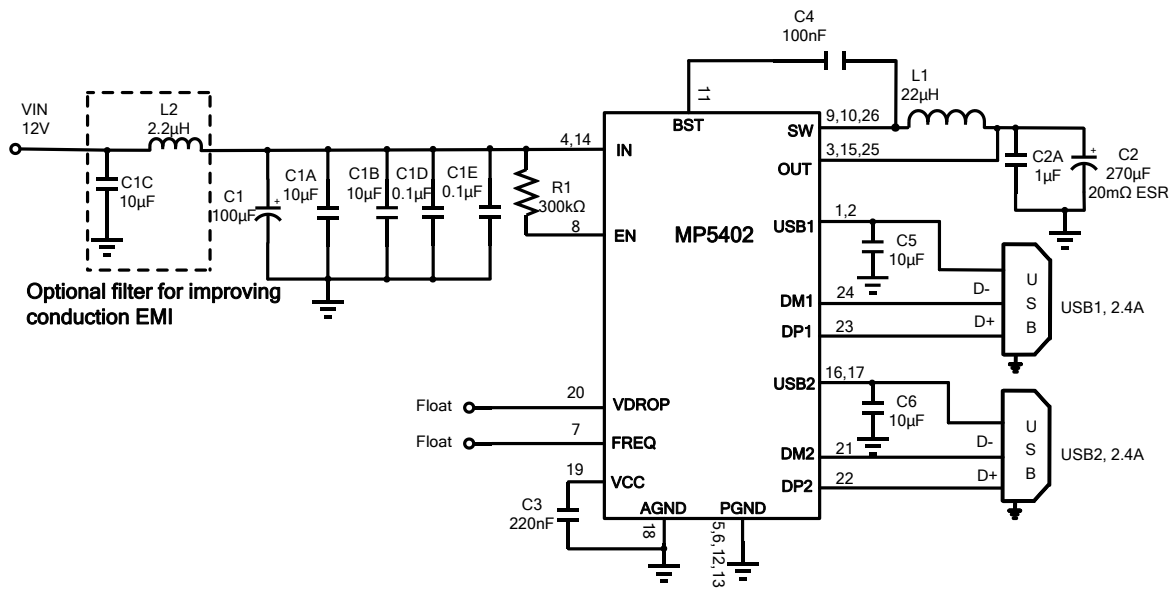
**Figure 5: Recommended Layout**

## TYPICAL APPLICATION CIRCUIT



**Figure 6: USB1 = 5V/2.4A, USB2 = 5V/2.4A**

# PACKAGE INFORMATION

## QFN-26 (4mmx4mm)

**PIN 1 ID MARKING**

**PIN 1 ID INDEX AREA**

3.90
4.10

3.90
4.10

**TOP VIEW**

0.25
0.35

0.50 BSC

18

17

0.45
0.55

24

**PIN 1 ID
0.10x45º TYP**

1.15
1.25

25

1
1.125
0.675
0.225
0.000
0.225

0.25
0.35

26

0.675
1.125

13

0.45
0.55

12

5

6

0.15
0.25

0.40 BSC

0.95
1.05

**BOTTOM VIEW**

0.80
1.00

0.20 REF

0.00
0.05

**SIDE VIEW**

3.30

0.30
0.50

0.10x45º

0.80

1.125
0.675
0.225
0.000
0.225
0.675
1.125

0.80

1.20

3.80

0.30

1.30

0.20

0.40

**RECOMMENDED LAND PATTERN**

<u>NOTE:</u>

1) ALL DIMENSIONS ARE IN MILLIMETERS.
2) EXPOSED PADDLE SIZE DOES NOT INCLUDE MOLD FLASH.
3) LEAD COPLANARITY SHALL BE 0.10 MILLIMETERS MAX.
4) JEDEC REFERENCE IS MO-220.
5) DRAWING IS NOT TO SCALE.