# MP86883

## Intelli-Phase™ Solution (Integrated HS/LS FETs and Driver) in 6x6mm TQFN

The Future of Analog IC Technology

## DESCRIPTION

The MP86883 is a monolithic half-bridge with built-in internal power MOSFETs and gate drivers. It achieves 55A of continuous output current over a wide input supply range.

Integration of the driver and MOSFETS results in high efficiency due to optimal dead time control and parasitic inductance reduction.

The MP86883 is a Monolithic IC approach to drive up to 55A per phase. This very small TQFN-34 (6mm x 6mm) device can operate from 100kHz to 1MHz.

This device works with tri-state output controllers. It also comes with a general-purpose current sense and temperature sense.

The MP86883 is ideal for server applications where efficiency and small size are a premium.

## FEATURES

- Wide 4.5V to 14V Operating Input Range
- Simple Logic Interface
- 55A Output Current
- Accepts Tri-State PWM Signal
- Built-In Switch for Bootstrap
- Current Sense
- Current Limit Protection
- Temperature Sense and Protection
- Fault Reporting
- Used for Multi-Phase Operation
- Available in TQFN-34 (6mm x 6mm) Package

## APPLICATIONS

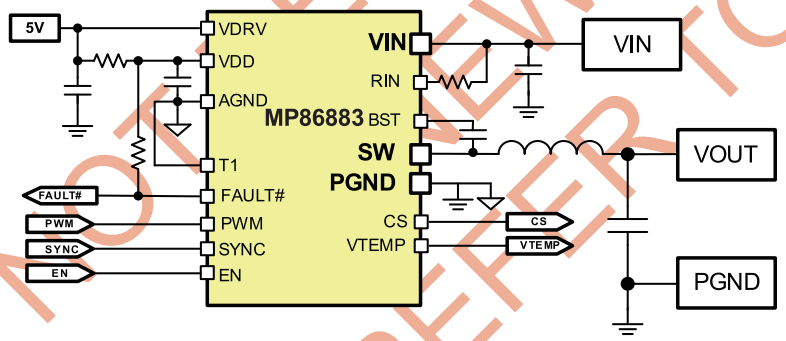
- Server/Workstation/Desktop Core Voltage
- Graphic Card Core Regulators
- Power Modules

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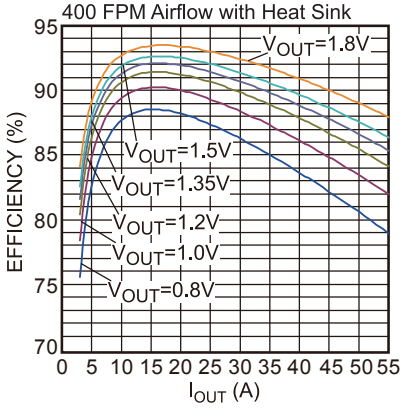
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## TYPICAL APPLICATION




**System Efficiency vs. Output Current**

L= FP1007R3-R21,
400 FPM Airflow with Heat Sink





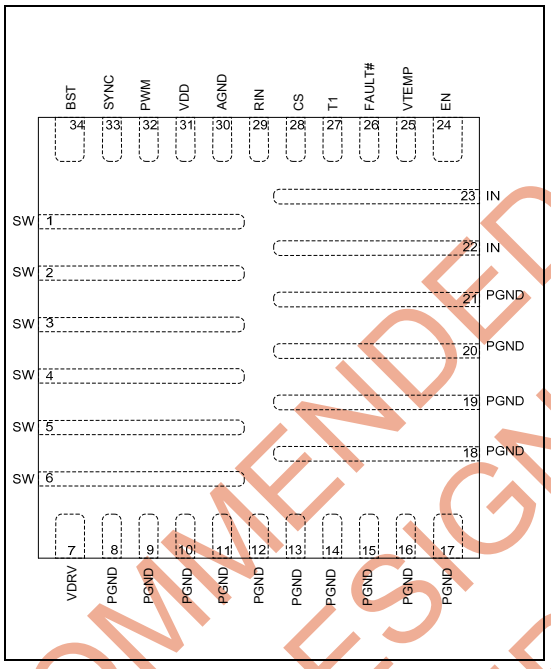
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## ORDERING INFORMATION

| Part Number* | Package | Top Marking |
|---|---|---|
| MP86883GQKT | TQFN-34 (6mmx6mm) | MP86883 |

* For Tape & Reel, add suffix –Z (e.g. MP86883GQKT–Z);

## PACKAGE REFERENCE




## ABSOLUTE MAXIMUM RATINGS (1)

Supply Voltage $V_{IN}$ ..... 16V
$V_{SW\ (DC)}$ ..... -1 V to 16V
$V_{SW\ (25ns)}$ ..... -3V to 23V
$V_{BST}$ ..... $V_{SW}$ + 6V
All Other Pins ..... -0.3V to +6V
Instantaneous Current ..... 100A
Continuous Power Dissipation ($T_A$ =+25°C)(2) ..... 4.3W
Junction Temperature ..... 150°C
Lead Temperature ..... 260°C
Storage Temperature ..... -65°C to +150°C

## *Recommended Operating Conditions* (3)

Supply Voltage $V_{IN}$ ..... 4.5V to 14V
Driver Voltage $V_{DRV}$ ..... 4.5V to 5.5V
Logic Voltage $V_{DD}$ ..... 4.5V to 5.5V
Operating Junction Temp. ($T_J$). -40°C to +125°C

## *Thermal Resistance* (4) $\theta_{JA}$ $\theta_{JC}$

| | | |
|---|---|---|
| TQFN-34 (6mmx6mm) | 29 | 8 °C/W |

**Notes:**

1) Exceeding these ratings may damage the device.
2) 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 will cause excessive die temperature, and the regulator will go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.
3) The device is not guaranteed to function outside of its operating conditions.
4) Measured on JESD51-7, 4-layer PCB.

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## ELECTRICAL CHARACTERISTICS (5)

**$V_{IN}$ = 12V, $V_{DRV}$=$V_{DD}$=5V, $T_A$ = -40°C to 125°C, unless otherwise noted.**

| Parameters | Symbol | Condition | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| $I_{IN}$ Shutdown | $I_{IN (Off)}$ | $V_{DRV}$=$V_{DD}$=0V | | 55 | | μA |
| $I_{IN}$ Standby | $I_{IN (Standby)}$ | $V_{DRV}$=$V_{DD}$=5V, PWM=EN=Low | | 60 | | μA |
| $V_{IN}$ Under Voltage Lockout Threshold Rising | | | | 4 | 4.4 | V |
| $V_{IN}$ Under Voltage Lockout Threshold Hysteresis | | | | 300 | | mV |
| $I_{DRV}$ Quiescent Current | $I_{DRV (Quiescent)}$ | PWM=Low | | | 500 | μA |
| $I_{DRV}$ Shutdown Current | $I_{DRV Shutdown}$ | | | 250 | | μA |
| $I_{DD}$ Quiescent Current | $I_{DD (Quiescent)}$ | PWM=Low | | 2.4 | | mA |
| $I_{DD}$ Shutdown Current | $I_{DD Shutdown}$ | | | 70 | | μA |
| VDD Voltage UVLO Rising | | | | 4 | 4.4 | V |
| VDD Voltage UVLO Hysteresis | | | | 300 | | mV |
| High Side Current Limit(5) | $I_{LIM}$ | | | 80 | | A |
| Low Side Current Limit(5) | | | | -30 | | A |
| EN Input Low Voltage | | | | | 0.4 | V |
| EN Input High Voltage | | | 2 | | | V |
| Dead-Time Rising(5) | | | | 3 | | ns |
| Dead-Time Falling(5) | | | | 8 | | ns |
| SYNC Current | $I_{SYNC}$ | $V_{SYNC}$=0V | | -65 | | μA |
| SYNC Logic High Voltage | | | 2 | | | V |
| SYNC Logic Low Voltage | | | | | 0.4 | V |
| PWM High to SW Rising Delay(5) | | | | 35 | | ns |
| PWM Low to SW Falling Delay(5) | | | | 35 | | ns |
| PWM Tristate to SW Hi-Z Delay(5) | $t_{LT}$ | | | 60 | | ns |
| | $t_{TL}$ | | | 50 | | |
| | $t_{HT}$ | | | 75 | | |
| | $t_{TH}$ | | | 50 | | |
| Minimum PWM Pulse Width(5) | | | | 30 | | ns |
| Current Sense Accuracy(5) | | $I_{OUT}$=30A | | ±4 | | % |
| Current Sense Gain | | | | 10 | | μA/A |
| Temperature Sense Gain(6) | | | | 10 | | mV/°C |
| Temperature Sense Offset(6) | | | | -100 | | mV |
| Over Temperature Flag(5) | | | | 170 | | °C |
| Over Temperature Hysteresis(5) | | | | 30 | | °C |
| PWM Input Current | $I_{PWM}$ | $V_{PWM}$=3.3V, $V_{EN}$=5V | | 95 | | μA |
| | | $V_{PWM}$=0V, $V_{EN}$=5V | | -95 | | μA |
| PWM Logic High Voltage | | | 2.65 | | | V |
| PWM Tristate Region(5) | | | 1 | | 1.7 | V |
| PWM Logic Low Voltage | | | | | 0.40 | V |

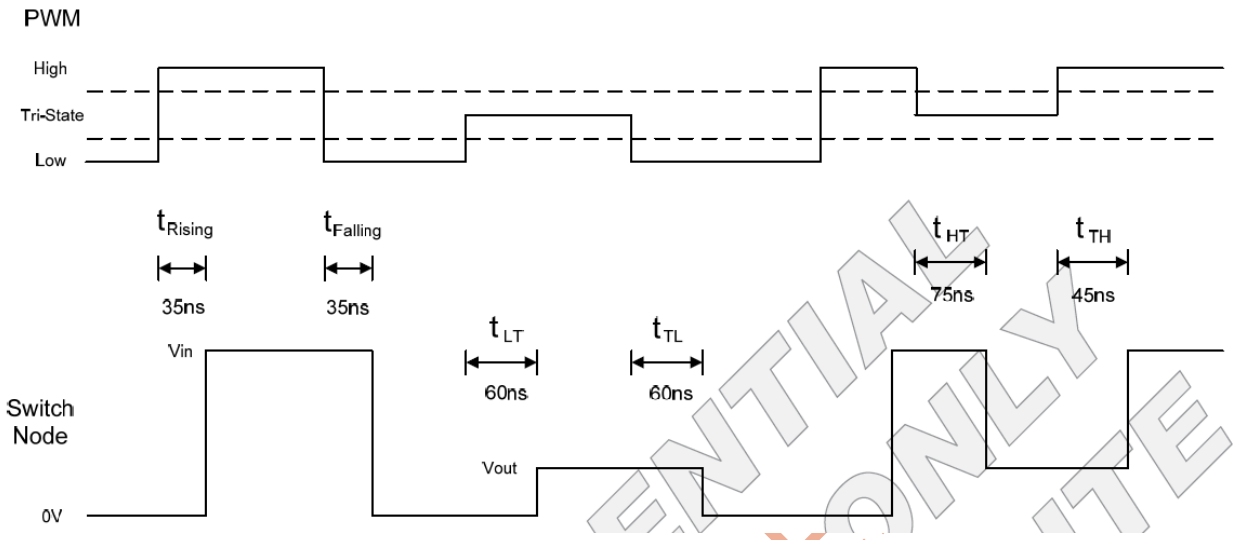
**Notes:**

**5)** Guaranteed by design.

**6)** See "Junction Temperature Sense" section for details.

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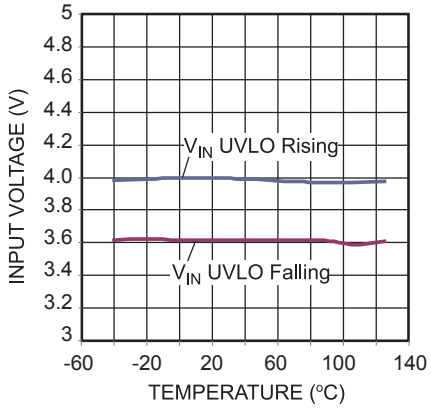



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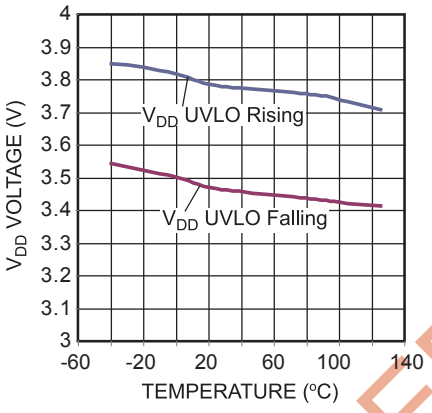

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## TYPICAL CHARACTERISTICS

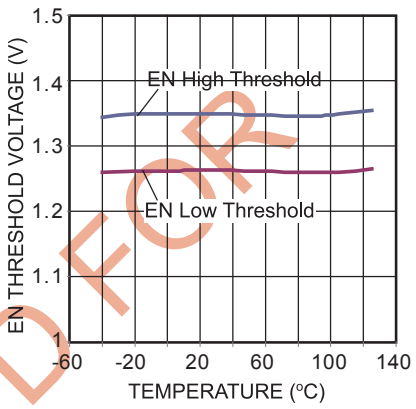
### $V_{IN}$ UVLO Threshold vs. Temperature



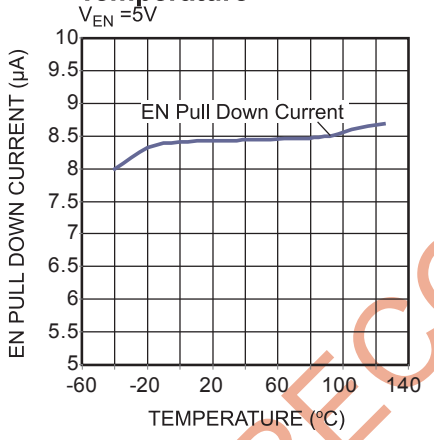

### $V_{DD}$ UVLO Threshold vs. Temperature



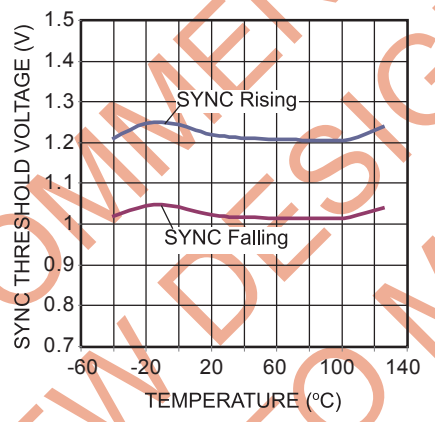

### EN Threshold vs. Temperature



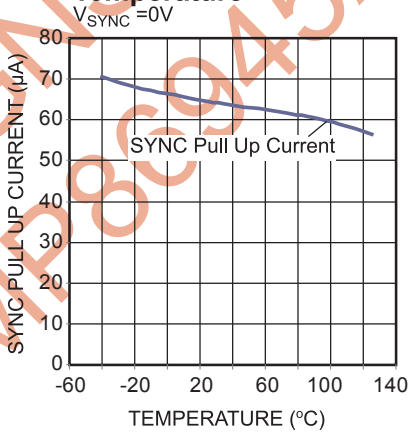

### EN Pull Down Current vs. Temperature



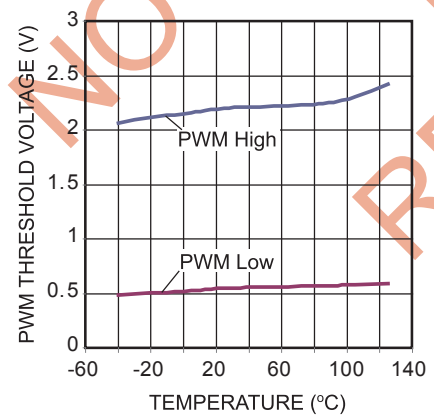

### SYNC Threhold vs. Temperature




### SYNC Pull Up Current vs. Temperature




### PWM Threshold vs. Temperature



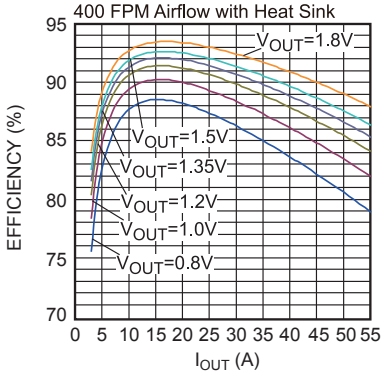

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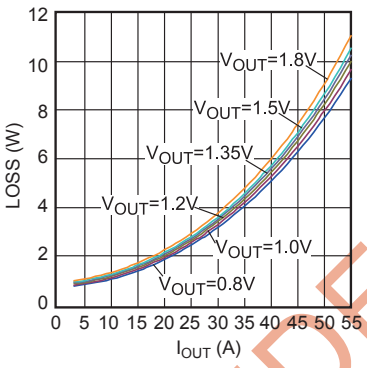
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$=12V, $V_{OUT}$=1.2V, $V_{DRV}$= $V_{DD}$=5V, L=215nH, $F_{SW}$=600kHz, $T_A$=25°C, no droop, unless otherwise noted.**

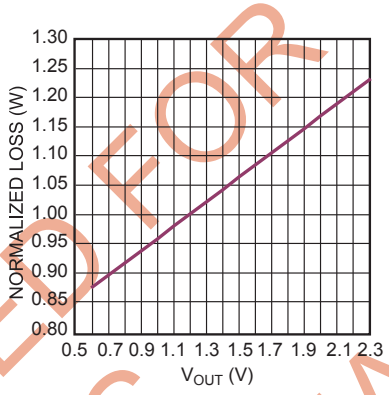
**System Efficiency vs. Output Current**
L= FP1007R3-R21,
400 FPM Airflow with Heat Sink



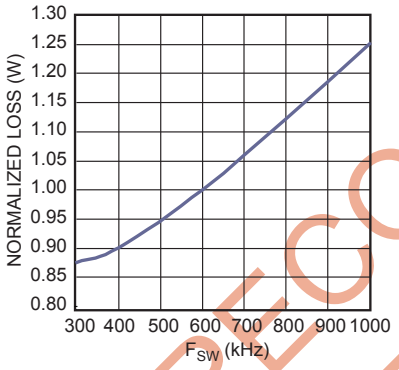

**Device Loss vs. Output Current**
400 FPM Airflow with Heat Sink



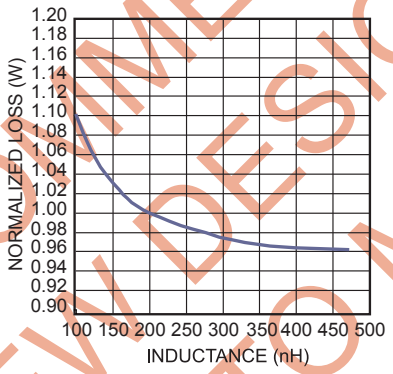

**Normalized Power Loss vs. Output Voltage**



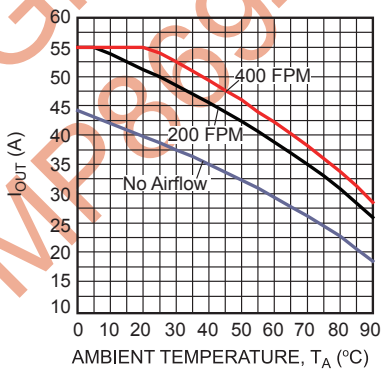

**Normalized Power Loss vs. Switching Frequency**



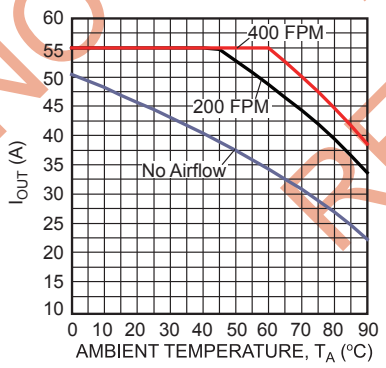

**Normalized Power Loss vs. Inductance**




**Safe Operating Area**
No Heat Sink




**Safe Operating Area**
With Heat Sink




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## PIN FUNCTIONS

| Pin # | Name | Description |
|---|---|---|
| 1-6 | SW | Switch Output. |
| 7 | VDRV | Driver Voltage. Connect to 5V supply and decouple with 1µF to 4.7µF ceramic capacitor. |
| 8-21 | PGND | Power Ground. |
| 22-23 | IN | Supply Voltage. Place $C_{IN}$ close to the device to prevent large voltage spikes at the input. |
| 24 | EN | Enable. Pull low to place SW in a high impedance state. |
| 25 | VTEMP | Single pin temperature sense output. |
| 26 | FAULT# | Fault reporting on HS current limit, Over Temperature and VDD UVLO. It is an open drain output during normal operation and pull-low when fault occurred. |
| 27 | T1 | Test pin. Connect to ground. |
| 28 | CS | Current Sense Output. Requires an external resistor. |
| 29 | RIN | Current Sense High Side Current Compensation pin. Connect through a resistor to IN. |
| 30 | AGND | Analog Ground. |
| 31 | VDD | Internal Circuitry Voltage. Connect to VDRV thru 2.2Ω resistor and decouple with 1µF capacitor to AGND. Connect AGND and PGND at this point. |
| 32 | PWM | Pulse Width Modulation. Leave PWM floating or drive to mid-state to put SW in high impedance state. |
| 33 | SYNC | Synchronous Low Switch. Leave open or pull high to enable. Pull low to enter diode emulation mode. |
| 34 | BST | Bootstrap. Requires a 0.22µF to 1µF capacitor to drive the power switch's gate above the supply voltage. Connects between SW and BST pins to form a floating supply across the power switch driver. |

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## BLOCK DIAGRAM

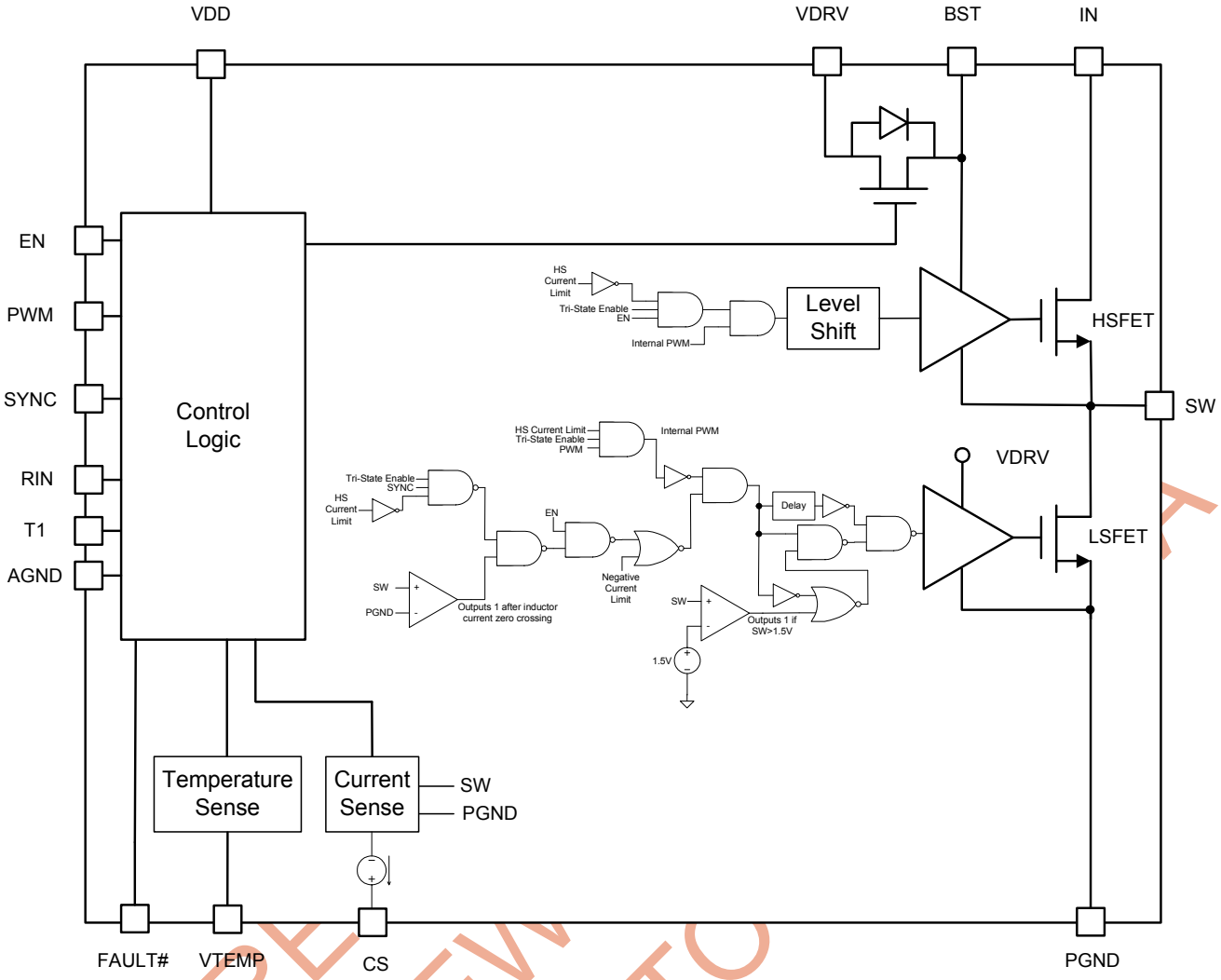



**Figure 1: Functional Block Diagram**

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## OPERATION

The MP86883 is a 55A monolithic half-bridge driver with MOSFETs ideally suited for multi-phase buck regulators.

When the EN transitions from low to high and both $V_{DD}$ and $V_{BST}$ signals are sufficiently high, operation begins. It is recommended to use EN pin to startup and shutdown the Intelli-Phase.

To put SW node in a high impedance state, let PWM pin float or drive PWM pin to mid-state. Drive the SYNC pin low to enter diode emulation mode. In diode emulation mode, the LSFET is off after inductor current crossed zero current.

When HSFET over current is detected, the part will latch off. Recycling Vdd or toggling EN will release the latch and restart the device. When the LSFET detects a -30A current, the part will turn off the LSFET for that cycle.

When Intelli-Phase detects over temperature, it will turn off both HS and LS MOSFET and latch off. Toggle Vdd or EN to restart the device.

### Current Sense

The CS pin is a bi-directional current source proportional to the inductor current. Use the following equations to select the RIN resistance to connect between RIN pin and IN pin:

$$R_{IN} = -7.55 \times I_{L_RIPPLE} + 170(k\Omega)$$

$$I_{L_RIPPLE} = \frac{t_{ON} \times (V_{IN} - V_{OUT})}{L} = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{V_{IN} \times F_{SW} \times L}$$

Where $I_{L_RIPPLE}$ is the peak to peak inductor ripple current. For example, if the ripple current is 10A, then the calculated $R_{IN}$ is 94.5kΩ and 95.3kΩ (the closest 1% resistor value) should be selected for $R_{IN}$.

The current sense gain is 10μA/A. In general, there is a resistor, $R_{CS}$, connected from CS pin and $V_{OUT}$ or an external voltage which is capable to sink small current to provide enough voltage shift to meet the operating voltage on CS pin.

The CS voltage range of 1V to 3.5V is required to keep CS's output current linearly proportional to inductor current. Use the following equations to determine a proper reference voltage and/or $R_{CS}$ value:

$$1V < I_{CS} \times R_{CS} + V_{REF} < 3.5V$$

$$I_{CS} = I_L \times 10 \times 10^{-6}$$

Intelli-Phase's current sense output can be used by controller to accurately monitor the output current. The cycle-by-cycle current information from CS pin can be used for phase current balancing, over current protection and active voltage positioning (output voltage droop).

Intelli-Phase's accurate current sense can replace traditional inductor DCR current sensing scheme. In traditional inductor DCR current sense:

$$V_{CS} = I_L \times R_{DCR}$$

With Intelli-Phase's CS output, $V_{CS}$ becomes:

$$V_{CS} = I_{CS} \times R_{CS} = I_L \times R_{CS} \times 10 \times 10^{-6}$$

Where the $R_{DCR}$ term is replaced with $R_{CS} \times 10 \times 10^{-6}$. Figure 2 shows a circuit replacing inductor DCR sensing with Intelli-Phase's CS output. There are several advantages with this current sensing method:

1. Since current sensing is done by Intelli-Phase, user can select low DCR inductors and still have large current sense signal by selecting larger $R_{CS}$.
2. Tight DCR variation is not required.
3. CS signal is independent of impedance matching and inductor temperature.

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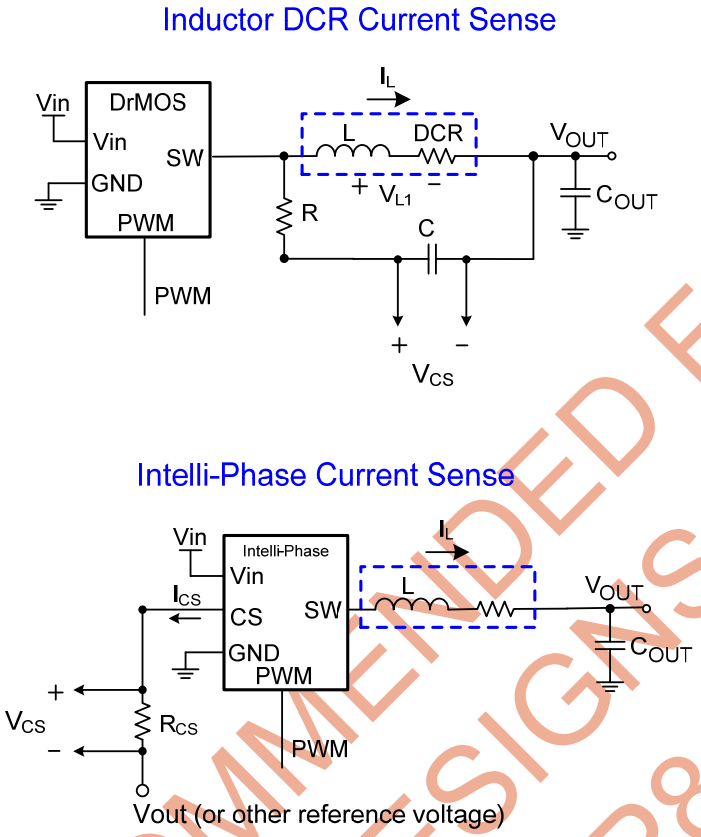



**Figure 2: Replacing DCR Current Sense with Intelli-Phase's CS Output**

### Junction Temperature Sense

The VTEMP pin is a voltage output proportional to the junction temperature. The junction temperature can be calculated from the following equation:

$$T_{JUNCTION} = \frac{(V_{TEMP} + 100mV)}{\frac{10mV}{^{o}C}},$$

for $T_{JUNCTION}$>10°C

For example, if the VTEMP voltage is 700mV, then the junction temperature of Intelli-Phase is 80°C. VTEMP can not go below 0V, so it will read 0V for junction temperature lower than 10°C.

Be sure to measure this voltage between VTEMP and AGND pins for the most accurate reading. In multi-phase operation, the VTEMP pins of every Intelli-Phase can be connected to the temperature monitor pin of the controller. A sample circuitry is shown in Figure 3. VTEMP signals can also be used for system thermal protection as shown in Figure 4.

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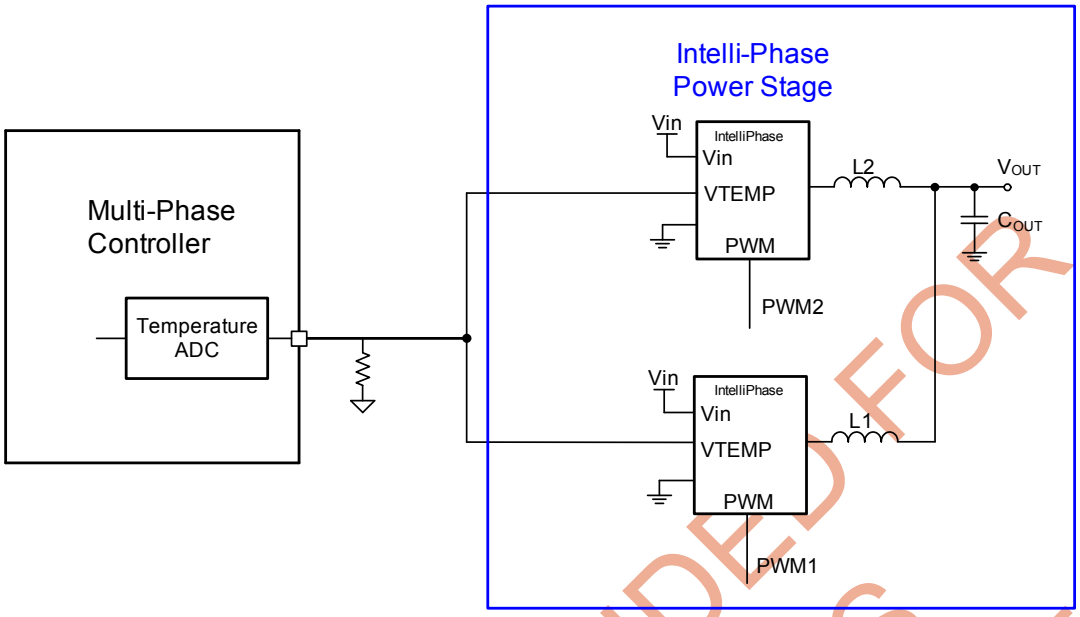



**Figure 3: Multi-Phase Temperature Sense Utilization**

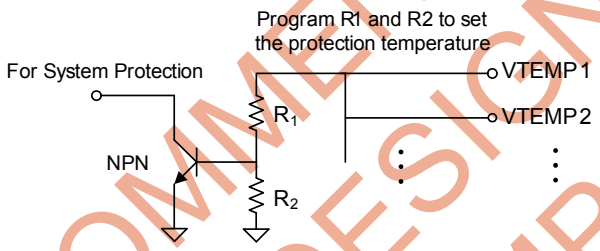



**Figure 4: System Thermal Protection**

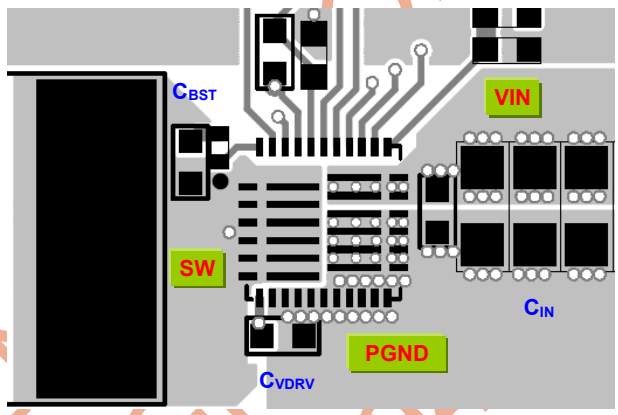
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### PCB Layout Guide Line

PCB layout plays an important role to achieve stable operation. For optimal performance, follow these guidelines.

1. Always place some input bypass ceramic capacitors next to the device and on the same layer as the device. Do not put all of the input bypass capacitors on the back side of the device. Use as many via and input voltage planes as possible to reduce switching spikes. Place the BST capacitor and the VDRV capacitor as close to the device as possible.
2. Place the VDD decoupling capacitor close to the device. Connect AGND and PGND at the point of VDD capacitor's ground connection.
3. It is recommended to use 0.22μF to 1μF bootstrap capacitor and 3.3Ω bootstrap resistance. Do not use capacitance values below 100nF for the BST capacitor.
4. Connect IN, SW and PGND to large copper areas and use via to cool the chip to improve thermal performance and long-term reliability.
5. Keep the path of switching current short and minimize the loop area formed by the input capacitor. Keep the connection between the SW pin and the input power ground as short and wide as possible.




NOT RECOMMEND FOR NEW DESIGN, REFER TO MP8692


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## TYPICAL APPLICATION CIRCUITS

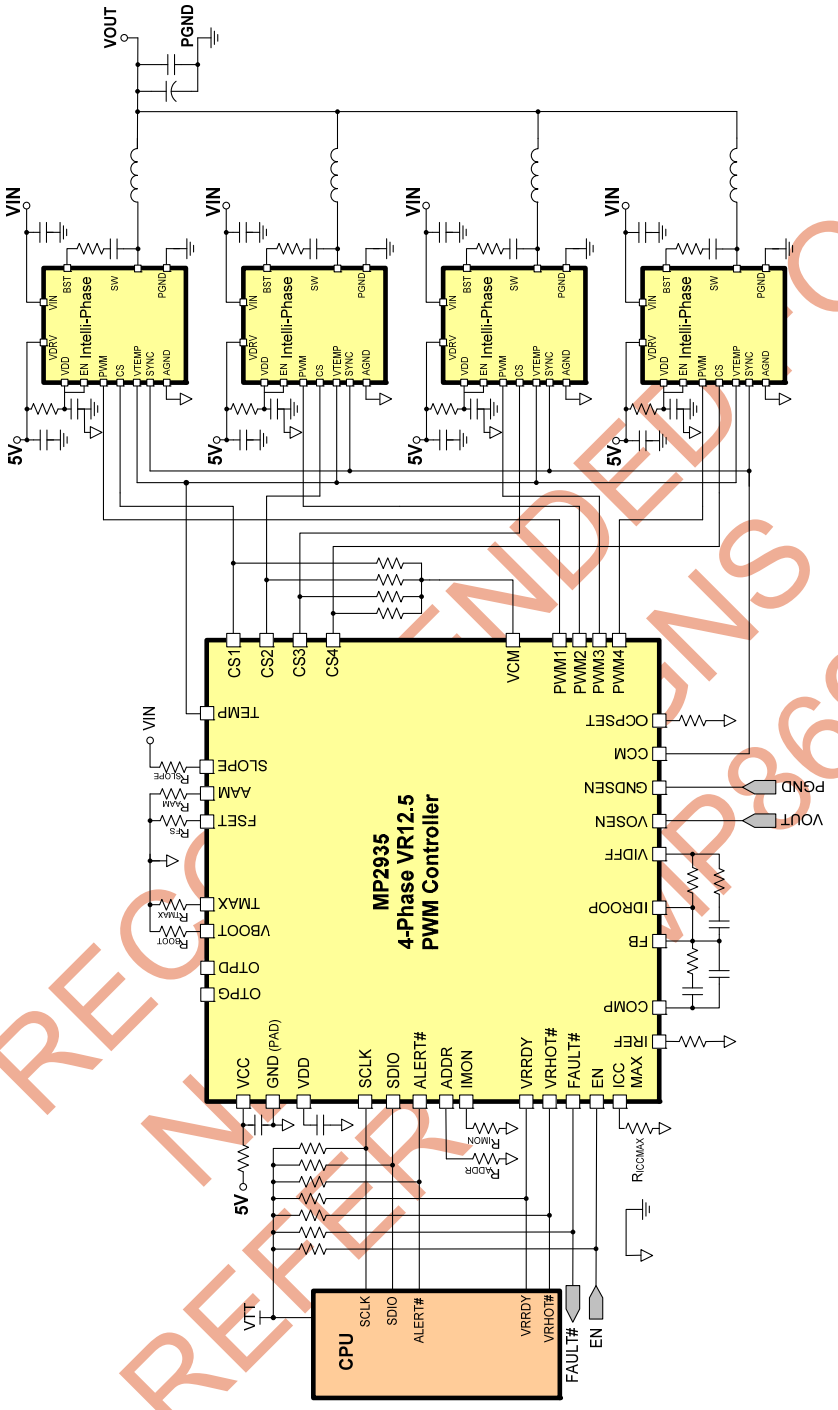


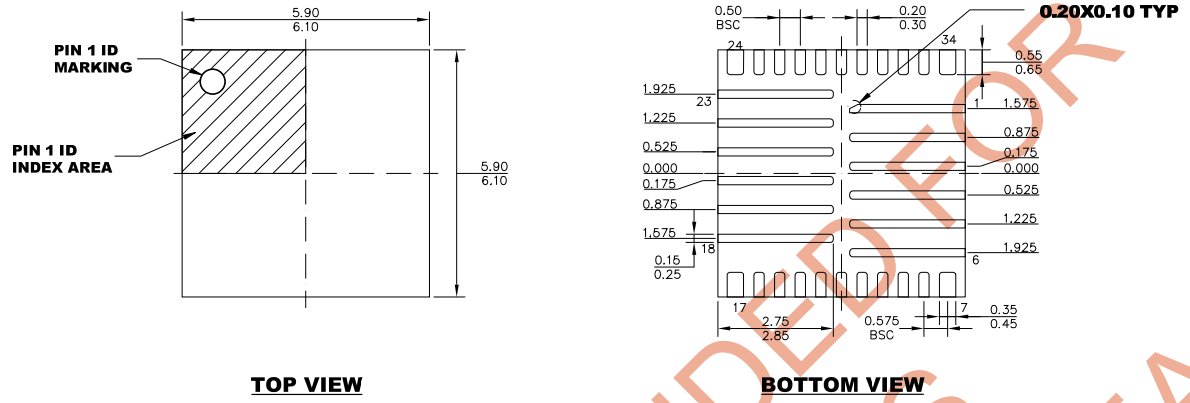

**Figure 5: 4-Phase Intelli-Phase with MP2935 VR12.5 Controller**

NOT RECOMMENDED FOR NEW DESIGNS REFER TO MP86945A

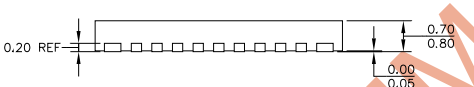

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# PACKAGE INFORMATION

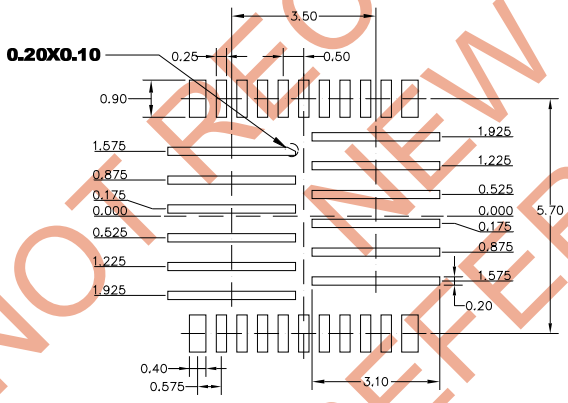
## TQFN-34 (6mm x 6mm)




**TOP VIEW** **BOTTOM VIEW**




**SIDE VIEW**




**RECOMMENDED LAND PATTERN**

**NOTE:**

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.

NOT RECOMMENDED FOR NEW DESIGNS REFER TO MP86945A

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