

## DESCRIPTION

The MP6515 is an H-bridge motor driver. It operates from a supply voltage of up to 35V and delivers motor current up to 2.8A. Typically, the MP6515 is used to drive a DC brush motor. For the MP6515, control of the outputs is accomplished through the PHASE, ENBL, BRAKE, and BMODE pins.

An internal current sensing circuit provides an output with voltage proportional to the load current. In addition, cycle-by-cycle current regulation/limiting is provided. These features do not require the use of a low-ohm shunt resistor.

Internal safety features include over-current protection, input over-voltage protection, under-voltage lockout (UVLO), and thermal shutdown.

The MP6515 is available in 16-pin 5.0mmx6.4mm TSSOP-EP and 3mmx4mm QFN package with exposed thermal pad.

## FEATURES

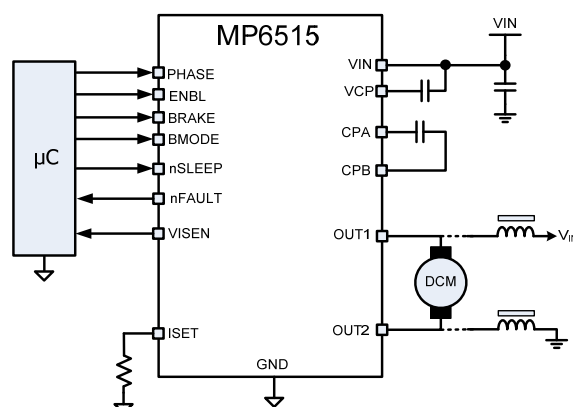
- Wide 5.4V to 35V Input Voltage Range
- 2.8A Peak Output Current
- Internal Full H-Bridge Driver
- PHASE/ENABLE control, input logic (PHASE, EN, BRAKE, BMODE)
- Cycle-by-Cycle Current Regulation/Limit
- Low On Resistance (HS:250mΩ;LS:250mΩ)
- Simple, Versatile Logic Interfaces
- 3.3V and 5V Compatible Logic Supply
- Over-Current Protection
- Over-Voltage Protection
- Thermal Shutdown
- Under-Voltage Lockout
- Fault Indication Output
- Thermally Enhanced Surface-Mount Package

## APPLICATIONS

- Solenoid Drivers
- DC Brush Motor Drive

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## TYPICAL APPLICATION



## ORDERING INFORMATION

| Part Number* | Package                     | Top Marking      |
|--------------|-----------------------------|------------------|
| MP6515GF*    | TSSOP-16 EP (5.0mm × 6.4mm) | <i>See Below</i> |
| MP6515GL**   | QFN-20 (3mm x 4mm)          | <i>See Below</i> |

\* For Tape & Reel, add suffix -Z (e.g. MP6515GF-Z)

\*\* For Tape & Reel, add suffix -Z (e.g. MP6515GL-Z)

### TOP MARKING (TSSOP-16EP)

**MPSYYWW**  
**MP6515**  
**LLLLLL**

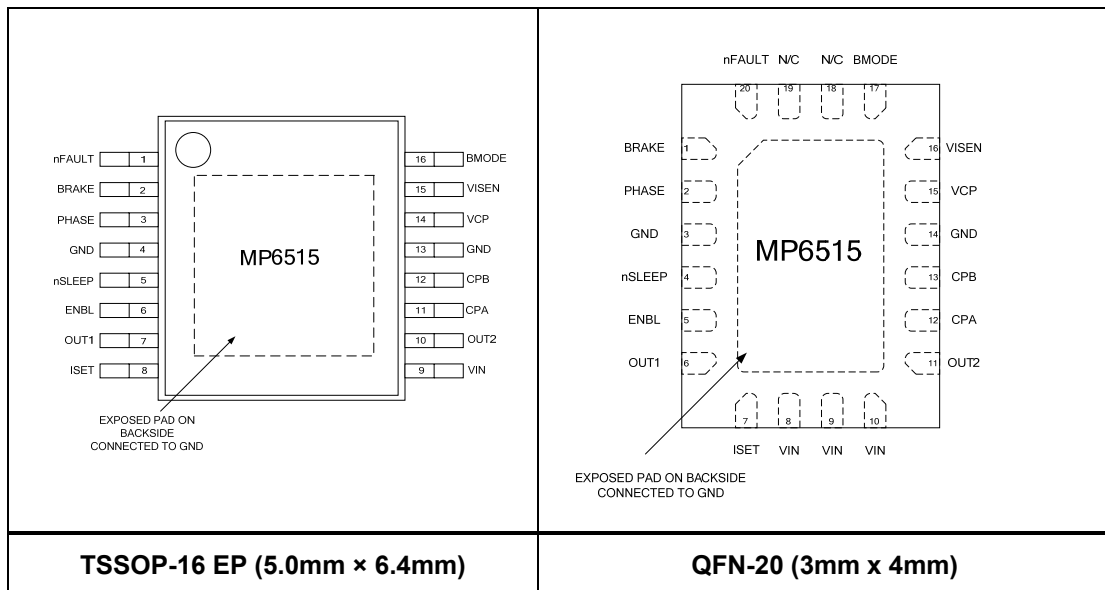
MPS: MPS prefix  
YY: Year code  
WW: Week code  
MP6515: Part number  
LLLLLL: Lot number

### TOP MARKING (QFN-20)

**MPYW**  
**6515**  
**LLL**

MP: MPS prefix  
Y: Year code  
W: Week code  
6515: First four digits of the part number  
LLL: Lot number

## PACKAGE REFERENCE



### ABSOLUTE MAXIMUM RATINGS <sup>(1)</sup>

|                                                                     |                           |
|---------------------------------------------------------------------|---------------------------|
| Supply voltage ( $V_{IN}$ )                                         | -0.3V to 40V              |
| OUTx voltage ( $V_{OUT1/2}$ )                                       | -0.7V to 40V              |
| VCP, CPB                                                            | $V_{IN}$ to $V_{IN}+6.5V$ |
| ESD Rating (HBD)                                                    | 2kV                       |
| ISET                                                                | -0.3V to 4.5V             |
| All other pins to GND                                               | -0.3V to 6.5V             |
| Continuous power dissipation ( $T_A = +25^\circ C$ ) <sup>(2)</sup> |                           |
| TSSOP-16 EP                                                         | 2.77W                     |
| QFN-20 (3mmx4mm)                                                    | 2.60W                     |
| Storage temperature                                                 | -55°C to +150°C           |
| Junction temperature                                                | +150°C                    |
| Lead temperature (solder)                                           | +260°C                    |

### Recommended Operating Conditions <sup>(3)</sup>

|                                         |                           |
|-----------------------------------------|---------------------------|
| Supply voltage ( $V_{IN}$ )             | 5.4V to 35V               |
| Continuous output current ( $I_{OUT}$ ) | $\pm 1.5A$ <sup>(4)</sup> |
| Load current ( $I_{VISEN}$ )            | $\pm 2mA$                 |
| Operating junction temp. ( $T_J$ )      | -40°C to +125°C           |

### Thermal Resistance <sup>(5)</sup>

|                  | $\theta_{JA}$ | $\theta_{JC}$ |
|------------------|---------------|---------------|
| TSSOP-16 EP      | 45            | 10 °C/W       |
| QFN-20 (3mmx4mm) | 48            | 10 °C/W       |

#### Notes:

- Exceeding these ratings may damage the device.
- 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.
- The device is not guaranteed to function outside of its operating conditions.
- Continuous current depends on PCB layout and ambient temperature.
- Measured on JESD51-7, 4-layer PCB

## ELECTRICAL CHARACTERISTICS

$V_{IN}=24V$ ,  $T_A = +25^{\circ}C$ , unless otherwise noted.

| Parameter                                 | Symbol           | Condition                                                | Min | Typ  | Max | Units       |
|-------------------------------------------|------------------|----------------------------------------------------------|-----|------|-----|-------------|
| <b>Power Supply</b>                       |                  |                                                          |     |      |     |             |
| Input supply voltage                      | $V_{IN}$         |                                                          | 5.4 | 24   | 35  | V           |
| Quiescent current                         | $I_Q$            | $V_{IN} = 24V$ ; nSLEEP = 1<br>No load current           |     | 1.5  | 2   | mA          |
|                                           | $I_{SLEEP}$      | $V_{IN} = 24V$ ; nSLEEP = 0                              |     |      | 1   | $\mu A$     |
| Charge pump frequency                     | $f_{CP}$         |                                                          |     | 680  |     | kHz         |
| <b>Internal MOSFETs</b>                   |                  |                                                          |     |      |     |             |
| Output on resistance                      | $R_{HS}$         | $V_{IN} = 24V$ , $I_{OUT} = 1A$ ,<br>$T_J = 25^{\circ}C$ |     | 0.25 | 0.3 | $\Omega$    |
|                                           |                  | $V_{IN} = 24V$ , $I_{OUT} = 1A$ ,<br>$T_J = 85^{\circ}C$ |     | 0.3  |     | $\Omega$    |
|                                           | $R_{LS}$         | $V_{IN} = 24V$ , $I_{OUT} = 1A$ ,<br>$T_J = 25^{\circ}C$ |     | 0.25 | 0.3 | $\Omega$    |
|                                           |                  | $V_{IN} = 24V$ , $I_{OUT} = 1A$ ,<br>$T_J = 85^{\circ}C$ |     | 0.3  |     | $\Omega$    |
| Body diode forward voltage                | $V_F$            | $I_{OUT} = 1.5A$                                         |     |      | 1.1 | V           |
| <b>Control Logic</b>                      |                  |                                                          |     |      |     |             |
| Input logic 'low' threshold               | $V_{IL}$         |                                                          |     |      | 0.8 | V           |
| Input logic 'high' threshold              | $V_{IH}$         |                                                          | 2   |      |     | V           |
| Logic input current                       | $I_{IN(H)}$      | $V_{IH} = 5V$                                            | -20 |      | 20  | $\mu A$     |
|                                           | $I_{IN(L)}$      | $V_{IL} = 0.8V$                                          | -20 |      | 20  | $\mu A$     |
| Internal pull-down resistance             | $R_{PD}$         |                                                          |     | 515  |     | k $\Omega$  |
| <b>nFault Output (Open-Drain Output)</b>  |                  |                                                          |     |      |     |             |
| Output low voltage                        | $V_{OL}$         | $I_O = 5mA$                                              |     |      | 0.5 | V           |
| Output high leakage current               | $I_{OH}$         | $V_O = 3.3V$                                             |     |      | 1   | $\mu A$     |
| <b>Protection Circuits</b>                |                  |                                                          |     |      |     |             |
| UVLO rising threshold                     | $V_{IN\_RISE}$   |                                                          |     | 5    | 5.3 | V           |
| UVLO hysteresis                           | $V_{HYS}$        |                                                          |     | 310  |     | mV          |
| Input OVP threshold                       | $V_{OVP}$        |                                                          | 36  | 38   | 40  | V           |
| Input OVP hysteresis                      | $\Delta V_{OVP}$ |                                                          |     | 2000 |     | mV          |
| Over-current trip level                   | $I_{OCP1}$       | Sinking                                                  | 3.2 | 4    | 5   | A           |
|                                           | $I_{OCP2}$       | Sourcing                                                 | 3.2 | 4    | 5   | A           |
| Over-current deglitch time <sup>(6)</sup> | $t_{OCPD}$       |                                                          |     | 500  |     | ns          |
| Over-current retry time                   | $t_{OCP}$        |                                                          |     | 0.9  |     | ms          |
| Thermal shutdown                          | $T_{TSD}$        |                                                          |     | 165  |     | $^{\circ}C$ |
| Thermal shutdown hysteresis               | $\Delta T_{TSD}$ |                                                          |     | 30   |     | $^{\circ}C$ |

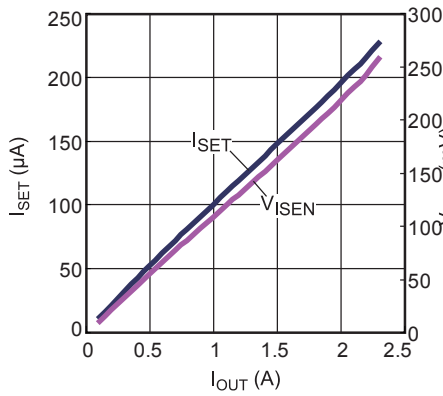
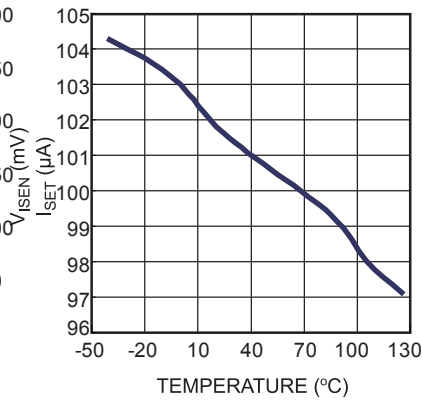
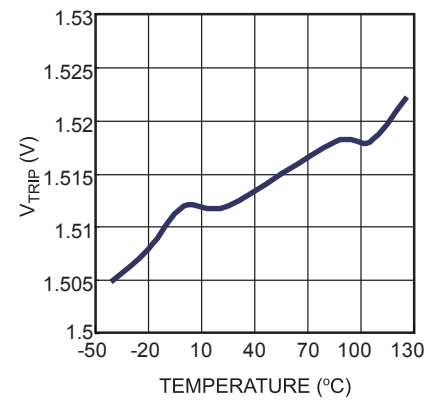
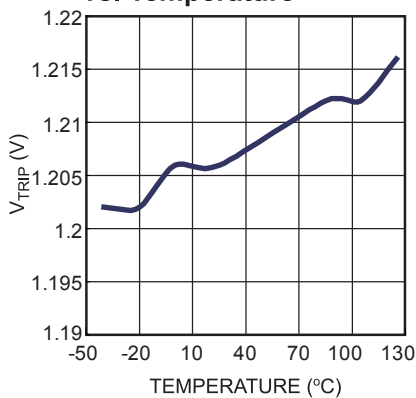
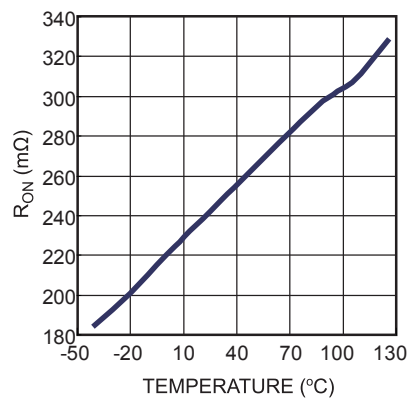
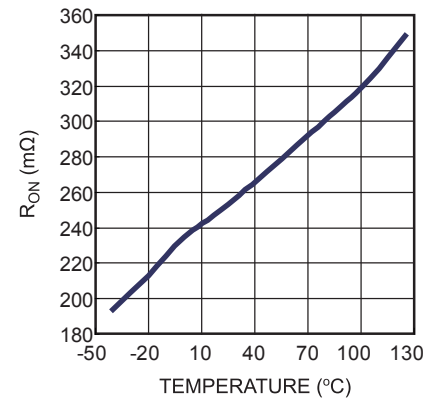
## ELECTRICAL CHARACTERISTICS

$V_{IN}=24V$ ,  $T_A = +25^{\circ}C$ , unless otherwise noted.

| Parameter                      | Symbol             | Condition         | Min  | Typ | Max  | Units     |
|--------------------------------|--------------------|-------------------|------|-----|------|-----------|
| <b>Current Control</b>         |                    |                   |      |     |      |           |
| Off time                       | $t_{ITRIP}$        | After ITRIP       |      | 16  |      | $\mu s$   |
| ISet current                   | $I_{SET}$          |                   | 90   | 100 | 110  | $\mu A/A$ |
| Current trip voltage (rising)  | $V_{ITRIP-R}$      | At VISEN pin      | 1.44 | 1.5 | 1.56 | V         |
| Current trip voltage (falling) | $V_{ITRIP-F}$      | At VISEN pin      | 1.15 | 1.2 | 1.25 | V         |
| <b>VISEN output</b>            |                    |                   |      |     |      |           |
| Output voltage accuracy        | $\Delta V_{VISEN}$ | $V_{ISET} > 0.5V$ | -5   |     | 5    | %         |

6) Guarantee by design

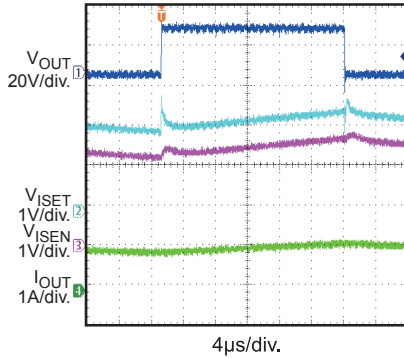
## TYPICAL CHARACTERISTICS

**Current Sense**
 $I_{SET}$  Resistor=1k

 **$I_{SET}$  vs. Temperature**
 $I_{OUT} = 1A$ 

**Current Trip Voltage (Rising) vs. Temperature**

**Current Trip Voltage (Falling) vs. Temperature**

**HS  $R_{ON}$  vs. Temperature**
 $I_{OUT} = 1A$ 

**LS  $R_{ON}$  vs. Temperature**
 $I_{OUT} = 1A$ 


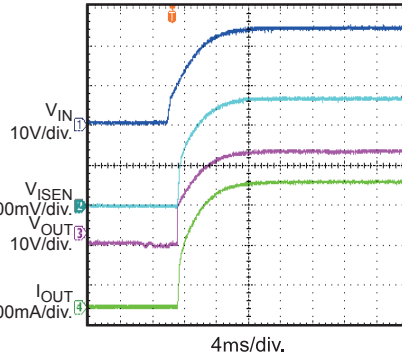
## TYPICAL PERFORMANCE CHARACTERISTICS

$V_{IN} = 24V$ ,  $I_{OUT} = 1A$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

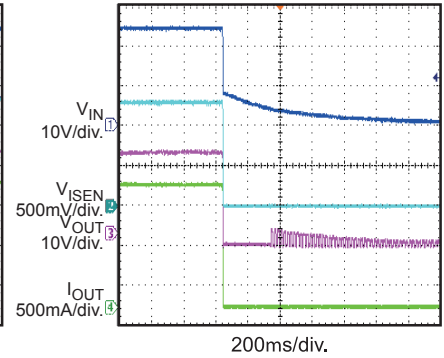
**Steady State**



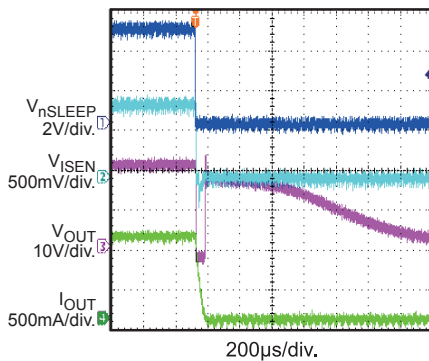
**Input Power Start-Up**



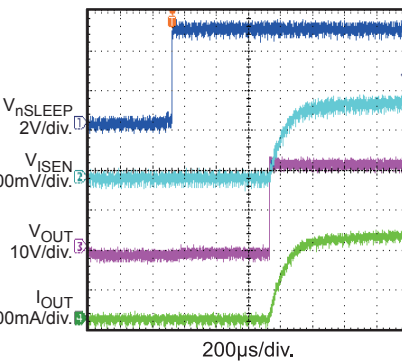
**Input Power Shutdown**



**Sleep Shutdown**

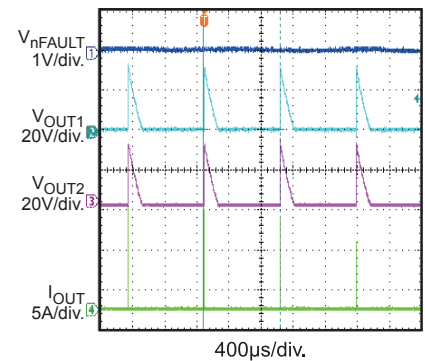


**Sleep Start-Up**



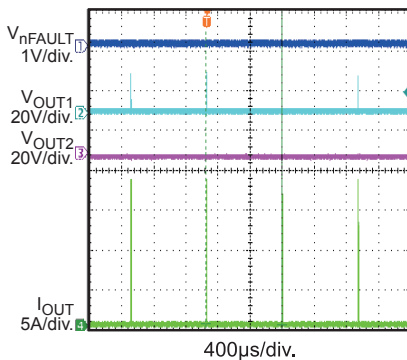
**SCP**

$V_{IN} = 35V$ , OUT1 Short to OUT2



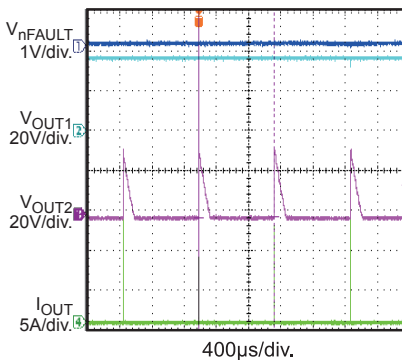
**SCP**

$V_{IN} = 35V$ , OUT1 Short to GND



**SCP**

$V_{IN} = 35V$ , OUT1 Short to VIN



## PIN FUNCTIONS

| TSSOP16<br>Pin # | QFN20<br>Pin # | Name   | Description                                                                                                          |
|------------------|----------------|--------|----------------------------------------------------------------------------------------------------------------------|
| 1                | 20             | nFAULT | <b>Fault indication.</b> Open-drain output, logic low when in fault condition (OCP, OTP, OVP).                       |
| 2                | 1              | BRAKE  | <b>Brake input.</b> Internal pulldown.                                                                               |
| 3                | 2              | PHASE  | <b>H-bridge phase input (motor direction).</b> Internal pulldown.                                                    |
| 4, 13            | 3, 14          | GND    | <b>System ground connection.</b>                                                                                     |
| 5                | 4              | nSLEEP | <b>Sleep mode input.</b> Logic low to enter low-power sleep mode. Internal pulldown.                                 |
| 6                | 5              | ENBL   | <b>H-bridge enable input.</b> High to enable H-bridge. Internal pulldown.                                            |
| 7                | 6              | OUT1   | <b>Output terminal 1.</b>                                                                                            |
| 8                | 7              | ISET   | <b>Current programming resistor.</b> Connect a resistor to ground to set the current limit and VISEN output voltage. |
| 9                | 8, 9, 10       | VIN    | <b>Input supply voltage.</b> Decouple to GND with a minimum 100nF ceramic capacitor to GND.                          |
| 10               | 11             | OUT2   | <b>Output terminal 2.</b>                                                                                            |
| 11               | 12             | CPA    | <b>Charge pump flying capacitor.</b> Connect a 100nF ceramic capacitor between CPA and CPB.                          |
| 12               | 13             | CPB    |                                                                                                                      |
| 14               | 15             | VCP    | <b>Charge pump output.</b> Connect a 100nF capacitor to VIN.                                                         |
| 15               | 16             | VISEN  | <b>Current sense output voltage.</b>                                                                                 |
| 16               | 17             | BMODE  | <b>Brake mode.</b> Internal pulldown.                                                                                |
| -                | 18, 19         | NC     | <b>No connection.</b>                                                                                                |
| EP               | EP             | GND    | <b>The exposed pad MUST be connected to ground.</b>                                                                  |

## BLOCK DIAGRAM

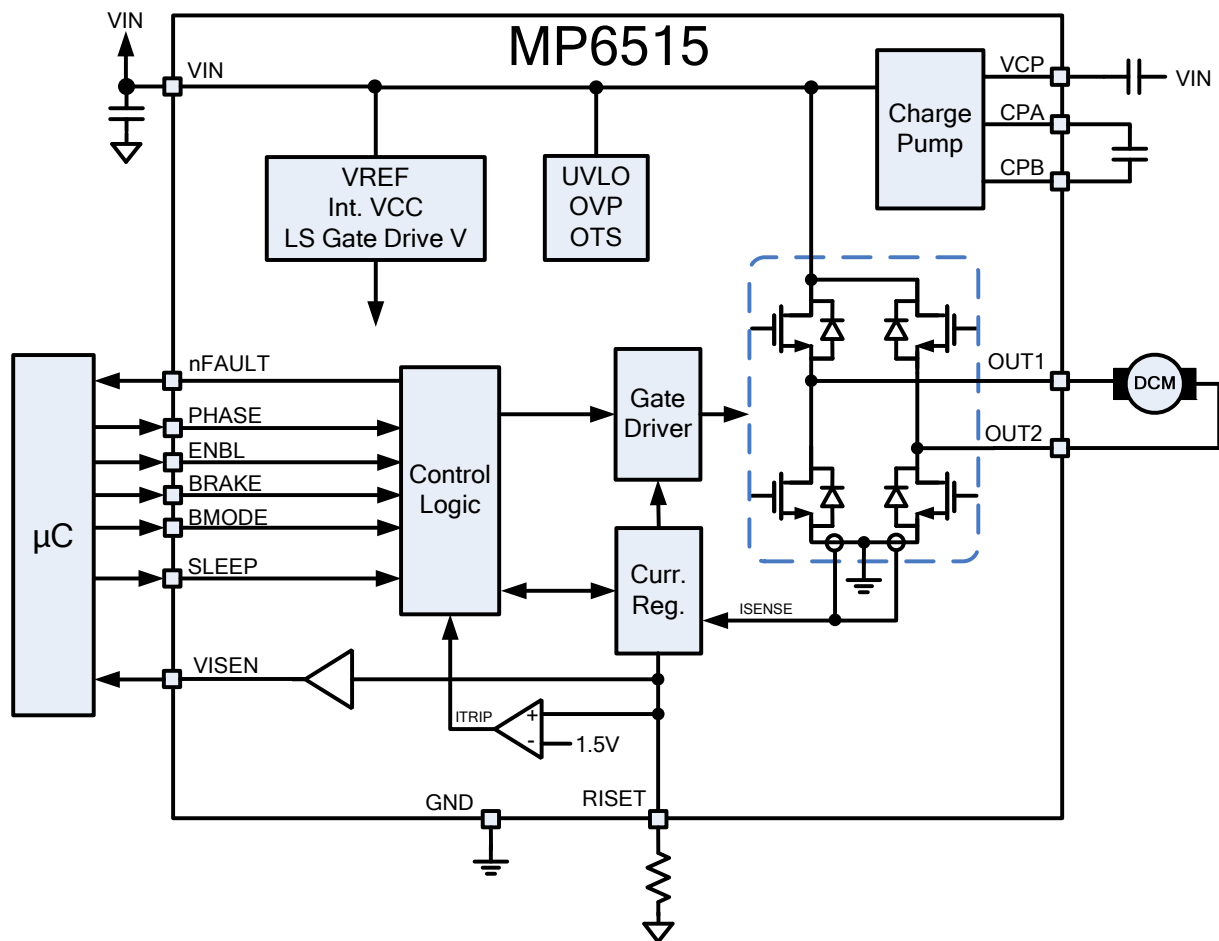


**Figure 1: Functional Block Diagram**

## OPERATION

The MP6515 is an H-bridge motor driver, which integrates four N-channel power MOSFETs with 2.8A peak current capability. It operates over a wide input voltage range of 5.4V to 35V. It is designed to drive bipolar stepper motors, DC brush motors, solenoids, or other loads.

### Current Sensing

The current flowing in the two low-side MOSFETs is sensed with an internal current sensing circuit. A voltage that is proportional to the output current is sourced on VISEN.

The VISEN output voltage scaling is set by a resistor connected between ISET and ground. For 1A of output current, 100 $\mu$ A of current is sourced into the resistor connected to ISET. For example, if a 10k $\Omega$  resistor is connected between ISET and ground, the output voltage on VISEN will be 1V/A of output current.

Current is sensed when one of the low-side MOSFETs is turned on, including during slow decay (brake) mode.

The load current applied to VISEN should be kept below 2mA, with no more than 500pF of capacitance.

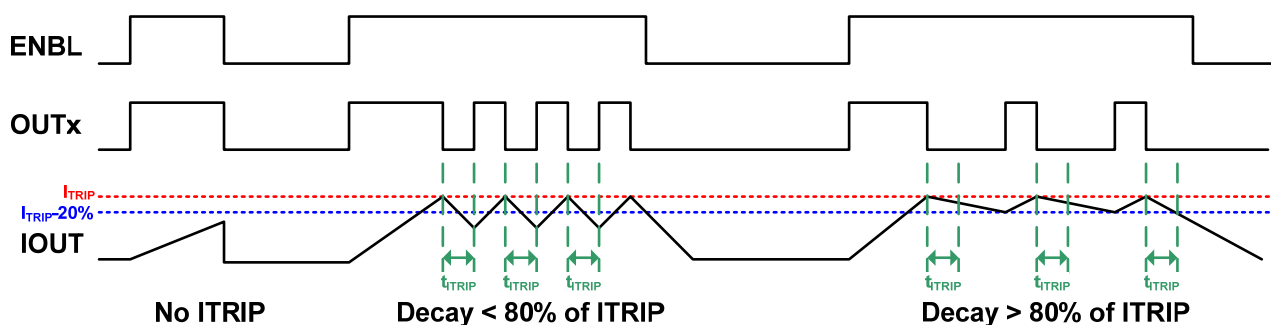
### Current Limit/Regulation

The current in the outputs is limited using constant off-time pulse width modulation (PWM) control circuitry. Operation is as follows:

- Initially, a diagonal pair of MOSFETs turns on and drives current through the load.
- The current increases in the load, which is sensed by the internal current sense circuit.
- If the load current reaches the current trip threshold, the H-bridge switches to slow decay mode, with the two low-side MOSFETs turned on.
- After a fixed off-time ( $t_{\text{TRIP}}$ ), if the load current falls at least 20% below the current limit threshold, the FETs are re-enabled and the cycle repeats.
- If the current is still higher than this level, the off time is extended until the current falls to 20% below the current limit threshold.

The current limit threshold is reached when VISEN reaches 1.5V. For example, with a 10k $\Omega$  resistor from ISET to ground, the VISEN voltage is 1V/A of output current. Therefore, when the current reaches 1.5A, VISEN voltage reaches 1.5V, and a current trip occurs.

During current regulation, nFAULT is not activated. See below:



### Blanking Time

There is often a current spike during the turn-on, due to the body diode's reverse-recovery current or the shunt capacitance of the load. This current spike requires filtering to prevent it from erroneously shutting down the high-side MOSFET. An internal fixed blanking time ( $t_{OCPD}$ ) blanks the output of the current sense comparator when the outputs are switched. This blanking time also sets the minimum on time for the high-side MOSFET.

### Input Logic

For the MP6515, control of the outputs is accomplished through the PHASE, ENBL, BRAKE, and BMODE pins. See Table 1:

Table 1: Output Control Pins

| ENBL | PHASE | BRAKE | BMODE | OUT1 | OUT2 | Function        |
|------|-------|-------|-------|------|------|-----------------|
| 1    | 0     | X     | X     | L    | H    | Reverse         |
| 1    | 1     | X     | X     | H    | L    | Forward         |
| 0    | X     | 1     | 0     | L    | L    | Brake (low)     |
| 0    | X     | 1     | 1     | H    | H    | Brake (high)    |
| 0    | 0     | 0     | X     | H*   | L*   | Sync fast decay |
| 0    | 1     | 0     | X     | L*   | H*   | Sync fast decay |

\* As the current through the H-bridge approaches zero, the outputs are tri-stated

### nSLEEP Operation

Driving nSLEEP low puts the device into a low power sleep state. In this state, all internal circuits, including the gate drive charge pump, are disabled, and the H-bridge outputs are turned off. All inputs are ignored when nSLEEP is active low. When waking up from sleep mode, time (approximately 1ms) must pass before the outputs will operate.

### Fault

The MP6515 provides an nFAULT pin, which is driven active low if any of the protection circuits are activated. These fault conditions include over-current, over-temperature, and over-voltage. nFAULT is not driven low when a current limit trip occurs. nFAULT is an open-drain output and requires an external pull-up resistor. When the fault condition is removed, nFAULT is pulled inactive high by the pull-up resistor.

### Over-Current Protection

The over-current protection circuit limits the current through each FET by reducing the gate drive to the FET. If the FET remains in the current limit condition for longer than the over-current deglitch time, all MOSFETs in the H-bridge will be disabled, and nFAULT will be driven low. The driver will remain disabled for  $t_{OCP}$ , at which point it will be re-enabled automatically. Over-current conditions are sensed on both high and low side devices; i.e., a short to ground, supply, or across the motor winding will result in an over-current shutdown. Note that over-current protection does not use the current sense circuitry used for PWM current control, and it is independent of the ISET resistor value.

### Over-Voltage Protection

If the input voltage applied to VIN is higher than the OVP threshold, the H-bridge output will be disabled, and nFAULT will be driven low. This protection is released when VIN drops to a safe level.

### Input UVLO Protection

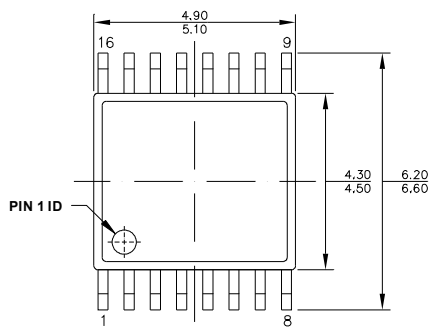
If at any time the voltage on VIN falls below the under-voltage lockout threshold, all circuitry in the device will be disabled and the internal logic will be reset. Operation will resume when VIN rises above the UVLO threshold.

### Thermal Shutdown

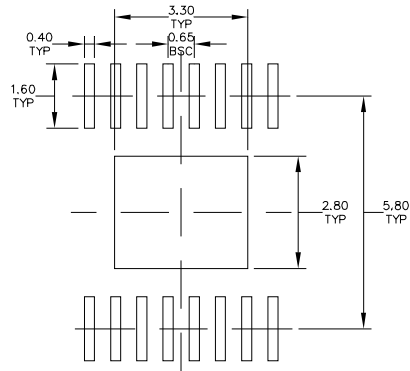
If the die temperature exceeds safe limits, all MOSFETs in the H-bridge will be disabled, and nFAULT will be driven low. Once the die temperature has fallen to a safe level, operation will resume automatically.

## PACKAGE INFORMATION

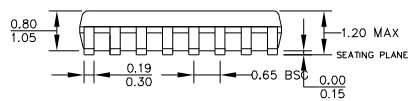
### TSSOP16-EP (5.0×6.4mm)



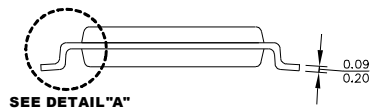
**TOP VIEW**



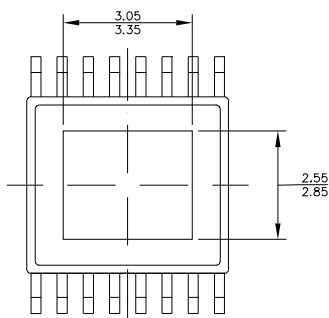
**RECOMMENDED LAND PATTERN**



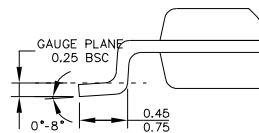
**FRONT VIEW**



**SIDE VIEW**



**BOTTOM VIEW**



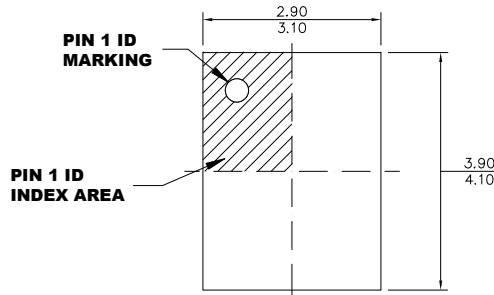
**DETAIL "A"**

#### **NOTE:**

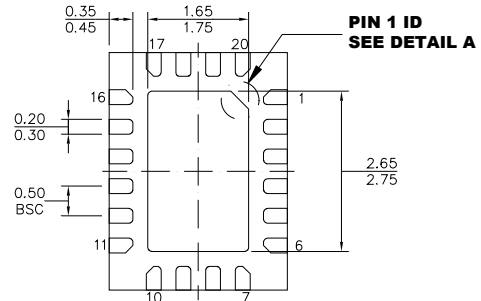
- 1) ALL DIMENSIONS ARE IN MILLIMETERS
- 2) PACKAGE LENGTH DOES NOT INCLUDE MOLD FLASH, PROTRUSION OR GATE BURR.
- 3) PACKAGE WIDTH DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSION.
- 4) LEAD COPLANARITY (BOTTOM OF LEADS AFTER FORMING) SHALL BE 0.10 MILLIMETERS MAX
- 5) DRAWING CONFORMS TO JEDEC MO-153, VARIATION ABT.
- 6) DRAWING IS NOT TO SCALE

## PACKAGE INFORMATION

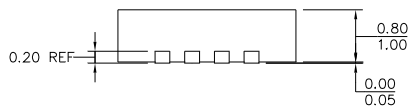
### QFN-20 (3mmx4mm)



**TOP VIEW**

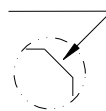


**BOTTOM VIEW**



**SIDE VIEW**

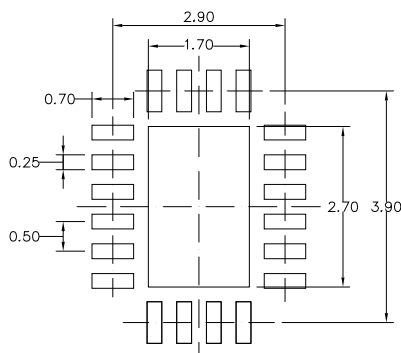
**PIN 1 ID OPTION A**  
0.30x45° TYP.



**PIN 1 ID OPTION B**  
R0.20 TYP.



**DETAIL A**



**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.

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